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Construction of Induction Coils and Transformers

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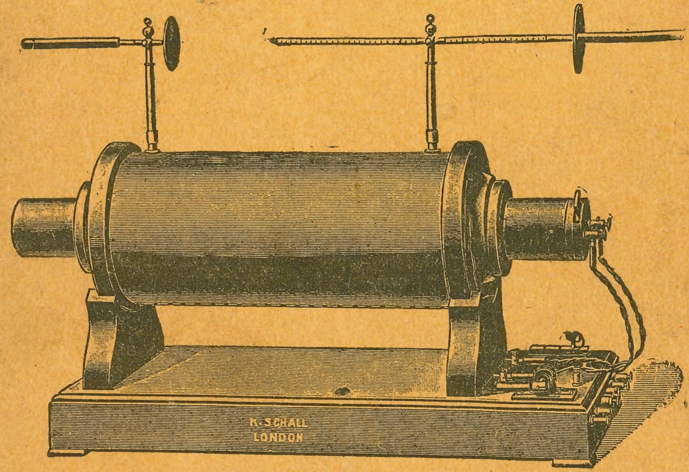


A 14 INCH SPARK COIL

72 ILLUSTRATIONS
100 PAGES

PRICE 25 CENTS

SECOND EDITION

Published by
Modern Publishing Company
231 Fulton Street
New York

Construction of Induction Coils and Transformers

A treatise on the design and construction of Induction Coils, Tesla Coils, and high tension Transformers for use in Wireless Telegraphy and X-Ray Work

Complied and Arranged by

H. WINFIELD SECOR

With several new chapters by the author

SECOND EDITION

1912

Published by MODERN PUBLISHING CO.
233 FULTON STREET
NEW YORK

Preface

This little book, has been brought out, in answer to numerous requests, for a handbook describing the design and construction of various sizes of Induction Coils and Transformers. As Editor of the question and answer Department of Modern Electrics, the information desired by the average experimenter is pretty well known, and an effort has been made to bring the work strictly up-to-date, with new data, and tables, compiled especially for it.

A section is devoted, to that extremely interesting instrument, the Tesla Coil, and instructions are given for the construction of a large coil of this type, suitable for demonstrations, such as given on the stage, lecture platforms, etc.

Details are given for the construction of open and closed core transformers, up to 3 Kilowatt capacity. The appendix contains several new tables, of value, to the coil builder, including weight of iron in cores, enameled wire data, etc.

The following works have been freely consulted: "Induction Coils," by Norrie. "Design and Construction of Induction Coils," by A. F. Collins. "Wireless Telegraphy and High Frequency Electricity," by H. La V. Twining.

With a little care and forethought on the part of the maker, a coil may be built after the designs offered in the following pages, and will give as good results as could be desired.

H. Winfield Secor.

New York, Oct., 1910.

CHAPTER I.

The Induction Coil.
Its History and Theory.

The induction coil as we know it to-day, is the outcome of developments extending back for three quarters of a century. The credit of constructing the first induction coil is generally given to Michael Faraday, the father of the dynamo, motor, and transformer, in virtue of the fact that he was the first man to discover that electricity could be generated in a coil of wire by the change in strength of the magnetic field surrounding it.

His first experiments with the production of secondary currents, were carried on with a closed iron ring, wound with two separate coils, one on either side of the ring. Later he made up a transformer, (which of course is nothing else than an induction coil) of the type we have to-day; consisting of a straight solid iron core, wound with a coil of a few turns of insulated wire, and over this another coil, or secondary of a large number of turns.

From that time on, the development of the induction coil has related mostly to the improvement of its various parts.

One of the first fundamental laws to be deduced on the action of the induction coil, was made by Lenz, in 1833, namely; that the direction of a current produced by electro-magnetic induction is always such, as to cause it to oppose the motion by which such currents were produced, and this is now known as LENZ'S LAW.

The first application of the vibrating contact breaker, or interrupter, known, was made by Callan, of Ireland. Shortly after this Sturgeon evolved a mechanical interrupter comprising a cup of mercury, with a wire dipping into it. The wire was caused to

be raised and lowered into the mercury as many times as thirty-six per second, by a cam and lever movement. A frequency of interruption of 540 times per second, was shortly afterward attained by using a revolving disc arrangement. All of these devices made use of, to make and break the primary current, were operated independently of the coil, but at about this time Bachhoffer, of Germany, brought out a self-acting interrupting device, which was the first automatic make and break appliance to be operated by the coil itself.

One of the greatest improvements ever made in the induction coil was the replacement of the solid iron core by a bundle of soft iron wires by Callan.

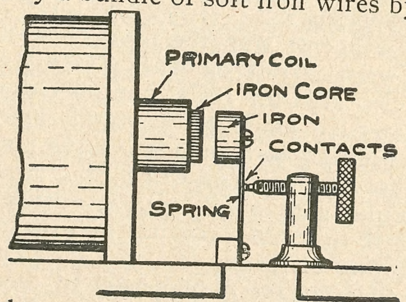


Figure 1

The scheme of drawing the fine secondary wire through a melted insulating compound while winding it on the coil, was also evolved by him. The method of winding the secondary coil in several sections, so as to subdivide the strain in it due to the very high voltage induced in same, is generally attributed to Poggendorf, of Germany, but is known to have been first utilized by Page.

The common spring vibrator, as illustrated in Fig. 1 was invented by Neef, of Germany, in 1840, and because it carries a small piece of soft iron at one end of the spring, it is called the Neef hammer interrupter.

The general efficiency of the induction coil was very much improved by Ruhmkorff, of France, in 1851, who

insulated the secondary from the primary by means of a glass tube placed over the primary coil, and also the addition of glass discs at the ends of the secondary coil. To Ruhmkorff is also given the credit of making the first commutator, or current reverser, for changing the direction of the primary current at will.

The final and possibly the most important improvement, relative to the efficiency of the induction coil, was the connection of a condenser across the interrupter terminals or contacts, by Fizeau of France, in 1851. See Fig. 2.

The induction coil and its various parts have been improved upon to such an extent, in the last twenty-

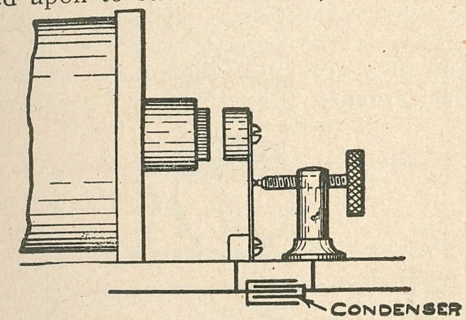


Figure 2

five years, that it is now possible to buy on order a standard coil, giving a spark fifty inches in length.

The action of the induction coil is due to the fact, that a current passing momentarily in the primary winding or coil, creates a magnetic field of force, which, when another coil of wire is placed within it with its axis parallel to that of the primary coil, induces in this coil a secondary current, whose voltage is proportional to the number of turns of wire it contains in comparison to the number of turns in the primary. Thus, if the primary coil contains 100 turns, and the secondary 50,000 turns, then if the primary has 10 volts flowing through it, the secondary will have 5,000 divided by 100 or 500 times 10 volts, induced in

it, which is equivalent to 5,000 volts; sufficient to jump an air gap one quarter of an inch long.

The action of the induction coil at make and break of the primary current, is best explained by looking at the following diagrams. As will be seen in Fig. 3 the direction of the induced current in the secondary is opposite to the direction of the primary current at make, which as will be remembered is in accordance with LENZ'S LAW. The half wave of the secondary current induced at the make of the primary circuit, is not of a very high value, and is known as the inverse current.

The conditions resulting from breaking the primary circuit, are exhibited at Fig. 4. The secondary induced current is now in the same direction as the primary current, and of a very high instantaneous value, also having much greater power, than the inverse half-wave.

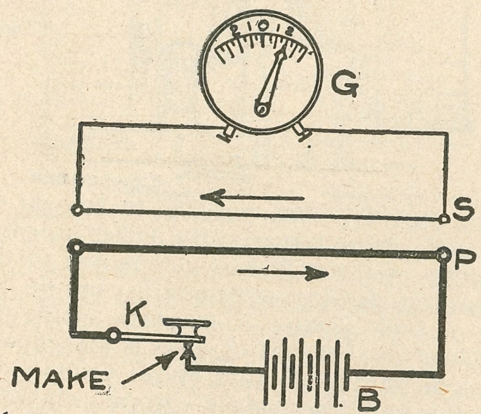


Figure 3

It will now be evident that in the ordinary induction coil, such as the medical coil, for instance; an intermittent direct current flowing in the primary winding, is transformed into an unsymmetrical alternating current in the secondary winding, the half waves not being harmonious.

In a spark coil, an intermittent direct current flowing in the primary, is transformed into an unsymmetrical alternating current in the secondary, providing the spark gap is sufficiently short to allow of the weaker or inverse half-wave of the current to jump it; otherwise if the gap is so long as to permit of only the half-waves resultant from breaking the primary circuit, jumping across it, then an intermittent direct current flows in the secondary. The polarity of this current may be found by the use of pole test-paper, or by attaching two pieces of fine iron wire to the secondary terminals, one of which will get very hot, while the other remains cold. The cold one is the positive terminal of the coil.

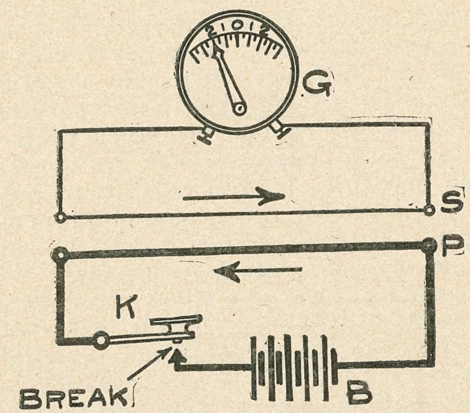


Figure 4

The most important feature is that the primary circuit shall be broken as abruptly as possible, and to aid this effect a condenser is shunted across the interrupter contacts, to absorb the extra or self-induced current of the primary, which would otherwise unduly prolong the demagnetization of the iron core. If this break can be made instantaneous, no condenser would be needed at all; also the faster the speed of interruption, the smaller the capacity of the condenser may be.

CHAPTER II.

COIL CONSTRUCTION.

By C. C. Whittaker.

On account of recent developments in wireless telegraphy and X-ray work, the induction coil, or inductorium, as it was first called, is now no longer confined to the laboratory as an interesting piece of apparatus; but, by its application to these comparatively newly discovered branches of science, has advanced till it is now almost a necessity in the electrical arts.

The proportions of the coil depend in a large measure upon the use to which the coil is to be put. In a long coil of small diameter, the secondary winding would, of course, be nearer the primary than that of a short thick coil; however, the former would be relatively slow in its action. The latter possesses the quality of quick action, but the outer turns of the secondary are so far removed from the most intense part of the field that its efficiency is seriously impaired. As a result of this, a compromise must be decided upon. Modern practice makes the length of the coil about twice as great as its diameter.

The proportions of the core follow the same general argument. The core must always have sufficient diameter so as not to strangle the magnetic flux, which flows through it. It is poor economy to make the core of small diameter for the purpose of saving wire. Good proportions for the core are given in the tables at the end of this book.

The size wire to be used is another varying factor depending on the nature of the spark desired. Number 36 to 40 gives a long thin spark; number 30 to 34 gives a shorter and fatter one. Larger wire than number 30 is seldom used. Modern wireless coils are now being built with number 30 wire on account of the greater efficiency. For the primary there is an ad-

vantage in using large wire. This allows plenty of current to flow, does not heat up readily, and enables the coil to demagnetize quicker than if it was wound with more turns of finer wire on account of the inductive effect which the latter would have.

Number 20 to 22 soft wire seems to be about the best for core construction. If this cannot be procured in the soft form, it may be softened in the following manner:

After the wires have been cut the proper length and straightened, the whole bundle should be bound tightly in four or five places with wire so as to bind the whole firmly together. This bundle is now laid

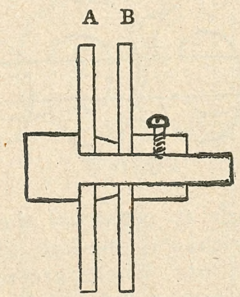


Figure 1

in a coal fire, where it is heated till nearly red hot, after which it is taken out and covered thoroughly with ashes. The object of this is to afford the bundle a chance to cool slowly. In all, it should take about two hours for this to cool sufficiently. If the bundle is heated too hot it will oxidize and thereby lessen the quantity of iron in the core. This cooling process having been completed, the ends of the core can now be squared off and the whole bound with one layer of fine, strong cord. Greater firmness will be secured if the core is now soaked in melted paraffine, or, better still, thick shellac.

The primary is now ready for winding. Usually

two layers of wire are enough. This brings the two ends out at the same end of the core.

The next subject under consideration regards the insulation which is to separate the primary and secondary windings. The best material for this is of course hard rubber, but this may prove expensive, especially if the coil is large. Compressed fibre can be obtained either black or red in color at a nominal price and forms a fairly good substitute. This fibre can be procured in any size, and the maker will do well to make his core and wind his primary before buying this tube. He will then be able to obtain an insulating tube that will tightly cover the primary.

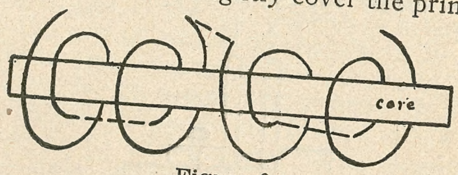


Figure 2

We are now ready to construct the secondary. All coils giving longer than a one-half inch spark should be built up in sections. These are made by winding the wire on a bobbin, one end of which can be readily slipped off. Fig. 1 gives a good idea of this arrangement, as shown by a cross section. The two large discs A and B should be faced on the inside with metal to prevent warping from the hot paraffine. Discs of thin hard cardboard, or, better still, of compressed fibre, are cut so as to have a hole in their center the diameter of which is to be equal to that of the tube covering the primary. The outer circumference has a diameter a little larger than that of the secondary winding. These are placed between each adjacent section. The sections should not exceed ¼ inch in thickness; for coils giving longer than a three-inch spark they should be even thinner. Every other section is wound in the opposite direction. The wire

should be run through melted paraffine, as it is wound onto the sections. This treatment cements the whole section together, increases insulation, and facilitates the handling of the section. The sections are connected by solder, as shown in Fig. 2.

The vibrator claims our attention next, the speed of vibration of which depends upon its size and weight. If a very rapid vibration is desired, the vibrator is made comparatively short; the soft iron head is made fairly light, a heavy head giving rise to slow vibrations. The full vibration is checked if the contact screw is placed so as to make contact near this head.

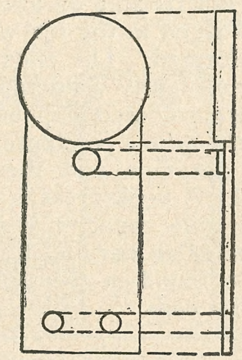


Figure 3

Fig. 3 shows a good form of vibrator. The contacts should be of sufficient size to carry all the current that is needed and should have their faces truly parallel. Negligence of this will result in nothing but inefficiency in the coil.

The contact screw must be provided with a check-nut, or other arrangement to maintain the adjustment.

The condenser is perhaps the most interesting adjunct of the coil. Its function is to "absorb" the extra induced current in the primary and, by the oscillatory nature of its discharge, to increase the output of the

secondary. It is made of alternate pieces of tin foil and paper. The shape or thickness of the tin foil is immaterial as far as results are concerned. For convenience, however, the condenser should, when completed, have the same proportions as the coil, so that it will fit nicely underneath the coil base. The paper used for this work should be entirely free from holes and should combine the qualities of thinness and strength. The paper which is used by grocers for wrapping fatty material in is good for this purpose; indeed, in some small coils bought ready made the condenser is made from old note-book paper or newspaper; but this is not reliable on account of the presence of a corroded metal in the ink whereby an arc or a short circuit is formed. The ends of the sheets of foil are most conveniently soldered to small brass strips to which are soldered copper wire terminals. When completed the whole condenser should be thoroughly boiled in paraffine and then pressed firmly together until cold. A book press is excellent for this purpose. If a variable capacity is desired, the condensers are connected in parallel by a switch. Condenser data will be found in the tables at the end of this book, for all size coils.

SECONDARY COIL IMPREGNATION.

By C. C. Whittaker.

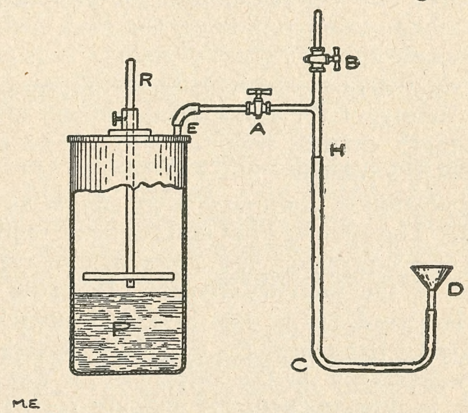
The efficiency of a home-made induction coil, in nine cases out of ten, falls much below the estimated efficiency before construction. This is due to a variety of causes which the amateur instrument maker finds it difficult to overcome. Such difficulties as not being able to "lay" the adjacent coils of the secondary close enough together and of not being able to sufficiently insulate these are common annoyances which seem to be inevitable.

The practice of winding a secondary by first letting the cotton or silk covered wire run through molten

paraffine certainly does insulate the wire, but it is practiced at great expense of space. A secondary wound with no paraffine and immersed in paraffine oil or linseed oil will behave well providing all the air can be expelled from the coils. The expulsion can best be accomplished by the aid of the air pump.

In the following paragraphs I shall endeavor to explain a method which is very satisfactory and easy to operate.

Looking at the illustration, the tank which contains the paraffine or oil should be one-half again as long



as the assembled secondary. This will allow the whole secondary to be suspended by the rod, R, above the paraffine or oil while the air is being exhausted.

The tank itself should be made of material sufficiently heavy to withstand the atmospheric pressure to which it will be subjected. The bottom edges should be soldered to render the tank airtight. The top edge is filed smooth so as to fit the plane surface of the top cover. This cover has the suspension rod running through its center and held in place by a set screw. Near one edge is soldered a small metal tube to serve as a connection for exhaustion.

This top is held in place by the atmospheric pressure from the outside. A soft rubber washer smeared with vaseline will effectually stop any air from entering while exhaustion is taking place. The suspension rod should also have a slight coating of vaseline.

The exhaustion can be carried on by any form of air pump. In case the experimenter has no pump at his command, the following description will be of interest to him:

A very efficient air pump can be made by the following directions with the aid of the illustration.

The T-shape tube containing the stop cocks A and B can be made either of glass or metal. It is connected to E by a piece of heavy rubber tubing. Another piece of tubing of the same diameter and about four feet in length extends from H to D. The end at D terminates in a funnel.

The operation of the pump is as simple as the construction. The tube H C D is filled with mercury. A is closed and B is open. The funnel is now raised until the level of the mercury rises to the stop cock B, when it is closed. D is now lowered somewhat more than thirty inches below B. A nearly perfect vacuum now forms between the top surface of the mercury and B. If A is now opened and quickly closed, the air in the tank will expand and fill the vacuum. D is now raised to the level of B and B is opened to allow the imprisoned air to escape. When the level of the mercury again reaches B, the valve is closed and the process is repeated.

When the exhaustion has been carried on to a sufficient degree the paraffine may be melted and the coil lowered into it by the rod R. After doing this it may be well to start the pump again on account of the gases given off by the hot paraffine.

After being thoroughly saturated, the coil may be lifted from the liquid and allowed to cool.

RATING SPARK COILS.

A good many amateurs labor under the wrong impression that the actual length of the spark of an induction coil is computed by the distance between the two spark balls.

This, of course, is erroneous. The length of the spark must be measured between two sharp metal points, as for instance a 1 inch coil will hardly ever give more than ¼" spark, measured between the balls. This is on account of the balls having a large capacity, which cuts the spark length down.

INCREASING THE EFFICIENCY OF SPARK COILS.

An interesting discovery has been made by an Englishman, Mr. A. Henry. He found that when he connected two Wehnelt interrupters in series his 1½" spark coil would give sparks up to 5¼", which at this length were even more intense than the original 1½" spark.

By means of rotating mirrors it was found that the frequency of the interruptions were 300 with one Wehnelt interrupter; by using two of same, the frequency ran up to 600. If the two interrupters are exactly alike, one observes in the rotating mirror that the platinum points get red hot alternately.

It is quite interesting, too, that by using two such interrupters in series the efficiency of a coil is greatly increased.

It was found that while with one interrupter and 90 volts across the primary and 8.5 amperes, the sparks obtained were 1½" long, but by using two interrupters with the same voltage, 5¼" sparks were obtained, and only 5 amperes were required.

No results were obtained by using two Wehnelt interrupters in parallel.

CHAPTER III.

INTERRUPTERS.

By A. P. Morgan.

One of the greatest sources of annoyance in operating an induction coil lies, without doubt, in the interrupter. Too much importance cannot be attached to this instrument, for upon it depends the satisfactory transmission of wireless messages, or the taking of an X-ray shadowgraph, etc.

In wireless telegraphy very faint signals are heard the most distinctly if the rate of interruption is high: The human ear is the most sensitive to sounds somewhat higher than the tones produced in wireless telegraphy. This seems to argue for a very high speed of interruption. It might be well to explain here that the rapidity of oscillation and speed of interruption are totally different from speed of break. The total speed of break is instantaneous and then no condenser is required.

Where a condenser is shunted across the secondary of an induction coil, as in a wireless transmitter, if the speed of interruption is too great, harmful oscillations are set up in the secondary. Again, if too fast, the rise and fall of the secondary currents will run into each other because the break will occur before the primary current has reached a maximum and the reverse secondary current has died away. As the core diameter of a wireless coil is generally larger than the ordinary there is also a great loss in energy, for with a rapid vibrator there is not sufficient time to properly magnetise it before the current is again broken. Another loss of energy is in the eddy currents and hysteresis lag, as these are directly proportional to the speed of the vibrator.

Thus it is seen that from the standpoint of the induction coil, a low rate of interruption is desirable. As there are other factors also to consider, the interrupter must be atonic or adjustable. An ideal interrupter is designed to give the longest possible time after the primary circuit is "made" and before the "break" occurs, which must be as sharp as possible.

A neat and efficient interrupter which fulfills these conditions and gives excellent results with small coils is illustrated in Fig. 1.

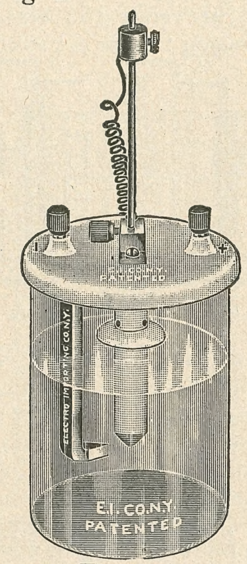


Figure 1

This interrupter, when connected in series with any coil from one to twelve inch spark, on to a 110 or 220 volt, direct or alternating current circuit, will increase the secondary output twofold. *Instead* of a thin, stringy spark, as given by the usual spring vibrator, a regular flame discharge is had, which is the best one, for wireless work and X-rays.

The periodicity of interruption, is from 5,000 to 7,000 interruptions per second, while the maximum speed of the spring vibrator is from 150-200 interruptions per second. It costs very little to operate, and is both economical and of low first cost.

Large coils generally use some form of mercury or turbine interrupter. The last named is essentially a centrifugal pump driven by an electric motor, and so arranged that it throws a revolving stream of mercury against a circle of brass teeth. Every time the mercury hits one of the teeth the circuit is made and when it passes between two it is broken.

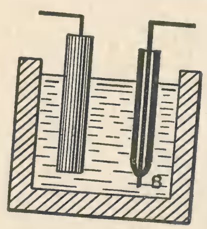


Figure 2

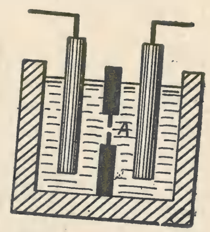


Figure 2a

The best form of interrupter for X-ray and experimental work is the electrolytic. The only disadvantage is that a potential of 40 volts or over is necessary. Fig. 2 shows the cross section of a Wehnelt and a Caldwell interrupter. The Wehnelt consists of a lead plate acting as a cathode and placed in a solution of dilute sulphuric acid. The anode is a piece of platinum wire (B) placed in a porcelain tube having a small hole in the bottom so that only a small amount of surface is exposed to the liquid. Upon the passage of a strong current through the electrolyte a succession of rapid interruptions, due to the formation of gases on the small electrode, take place and are adjustable through great ranges by raising or lowering the platinum wire and thus increasing or decreasing the surface exposed. The only disadvantage is that with

heavy currents the liquid becomes quickly heated and the gases prevented from forming freely.

Such an interrupter may be easily improvised by sealing a piece of No. 22 platinum wire (Fig. 3, C) in one end of a glass tube and immersing it with a lead plate or rod in a solution of sulphuric acid (dilute).

The Simon or Caldwell interrupter operates by exceeding a certain current density at one part of a solution. It consists of a vessel containing dilute sulphuric acid as an electrolyte which is divided into two parts by means of a diaphragm or partition hav-

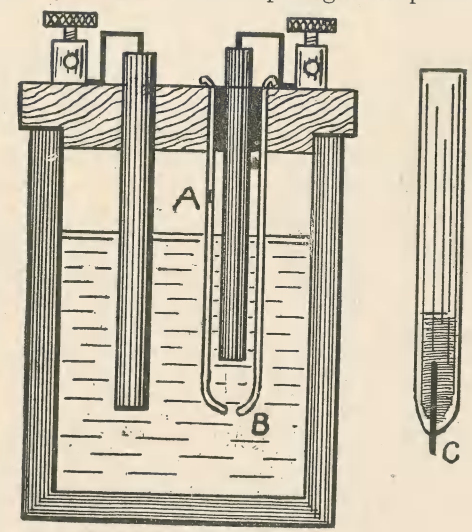


Figure 3

ing a small hole in the center. Connection is made to the two sections of the electrolyte by strips of lead. (Fig. 2A).

If the end of a hard glass tube is heated with a pin flame and then a hole varying from 1-32 to 3-32 of an inch made in it by blowing on the open end of the tube and thus bursting the soft glass, it may be made

to serve as an excellent Simon Caldwell diaphragm. It should be set up in a glass jar and supported by a wooden cover as in Fig. 3. Two leaden rods are placed in the electrolyte, one inside the tube and the other outside. The smaller the hole the higher the rate of interruption and the smaller the amount of current flowing.

Both of the improvised types of electrolytic interrupter described above are non-adjustable. If any range of work is to be attempted in experimenting they should be made adjustable. Fig. 4 gives a scheme

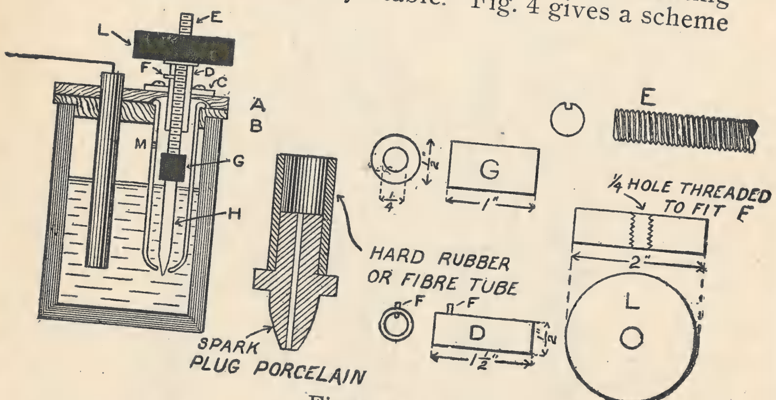


Figure 4

for an efficient interrupter of both types, and which may be very closely adjusted.

It is desirable that in raising or lowering the electrode the motion imparted be perpendicular and not rotary. This is accomplished in the following manner: A piece of so-called ¼-inch "brass" curtain rod which in reality generally consists of an iron rod covered by a thin sheet of brass, the edges of which are folded over into a groove. A piece of such rod is stripped of its brass and threaded as shown by E in Fig. 4. A piece of ¼-inch brass tubing 1½ inches long (D) is fitted with a pin (F) projecting through

so that when the tube is placed over the rod E the pin will engage the slot and the rod may be slid in or out of the tube but not twisted. The tube is passed through the wooden cover of the interrupter jar and held perpendicular by soldering to a large brass washer (C). The brass washer is bored to receive two small screws which fasten it to the cover. A large nut made of fibre or hard rubber serves as an adjusting handle. It is about 2 inches in diameter and ⅝ inch thick. It is threaded to screw on the rod E and thus raise or lower it when revolved. The pin F prevents the rod E from revolving. The porcelain of a spark plug is fitted tightly into a fibre or hard rubber tube and serves to shield the wire, used as the anode, from the liquid save at its point or end. The reason porcelain is used is that it does not crack easily. A piece of platinum wire to fit the hole in the porcelain is fastened to E. The porcelain and its supporting tube are fastened below the rod E to the cover.

The Simon Caldwell interrupter makes use of the same mechanism, save that the size of the hole in the test tube is adjustable in size or area by raising and lowering a ¼-inch pointed glass rod into it. (See H in Fig. 4.) H and E are connected by G, which is a piece of fibre or hard rubber tubing fitting tightly over both. The cover of the jar consists of two parts, A and B, one supporting the adjustable electrode, or in this case the glass rod, and the other the test tube or hard rubber tube and porcelain in the case of the Wehnelt type.

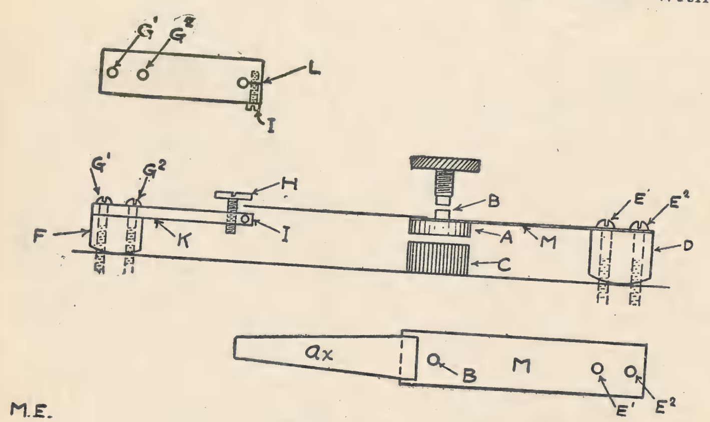
Holes (A, Fig. 3, and M, Fig. 4) are always made in the tubes above the level of the electrolyte. The liquid tends to rise in the inside of the tube, and by this means is permitted to flow back into the jar. A deep jar is desirable and the wooden cover should be paraffined. The lengths of the various parts are somewhat optional and may be made to suit the depth of the jar.

HOW TO BUILD AN EFFICIENT VIBRATOR.

By "A. S. N."

After experimenting on coil vibrators for several years, and giving the different devices practical service, I have found that coils will do more than is expected from them if a proper vibrator is used in conjunction with them.

The following description is of a vibrator which has proven to be the most satisfactory and rapid vibrator I have ever used or seen, and has been used by myself and a few of my friends on coils up to 4 inches with



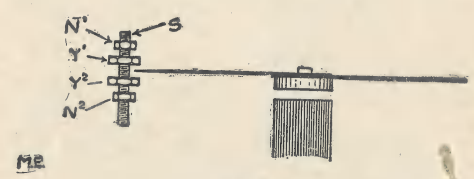
-FIG. 1-

the same gratifying results. The object in this construction is to get a rapid hammer blow action both to and away from the contact points. This is done by relieving the main spring M in Fig. 1 of part of the weight of armature A by adding an extra spring Ax at end of spring M, and have means to limit its range which is done by placing the extreme end, between two adjustable, solid contacts shown at H and K. When K is so adjusted (at the block F to which it is fastened)

by means of adjusting screws G1, G2, armature A is drawn slightly away from core at C. After main spring M has been adjusted the proper distance from C by means of block D (which is fastened solid to M) and adjusting screws E1 and E2, screw H should then be set so distance between under side of its head and K is slightly more than the thickness of the spring Ax. K should be slotted as shown by L and tapped out for a lock screw I to prevent screw H from working out of adjustment.

A simple arrangement is shown in Fig. 2, and in which the results are about the same. Although it must be said it is harder and rather inconvenient for quick adjusting.

The springs of this arrangement are the same as in Fig. 1. S shows a screw or threaded brass rod set in



-FIG. 2-

head of the coil and on which are two nuts, Y1 and Y2, corresponding to H and K in Fig 1. N1 and N2 are lock nuts for nuts Y1 and Y2. For above vibrators the electrical connections are the same as the ordinary vibrator; the additional parts being for mechanical action.

A little experimenting will soon enable one to quickly adjust the above vibrators without any trouble, which when properly done, will be found very adaptable for wireless work. Fig. 2 is to be adjusted in same manner as Fig. 1. As so much depends on the springs, especially spring Ax, which must be stiff and light, it would be useless to try to give further directions for adjusting.

CONSTRUCTION OF AN INDEPENDENT VIBRATOR.

By L. SPANGENBERG.

Perhaps some of the readers of this book will be interested in an instrument of this kind to replace the ordinary core type of vibrator, which gives the operator so much trouble while sending by sticking and producing a lagging spark. The difference, however, is not noticeable until after having used an independent vibrator. It will be found that this instru-

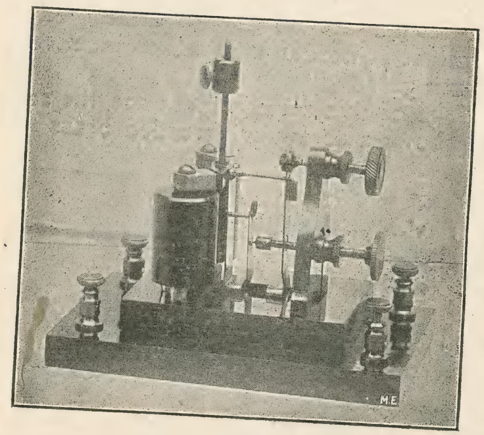
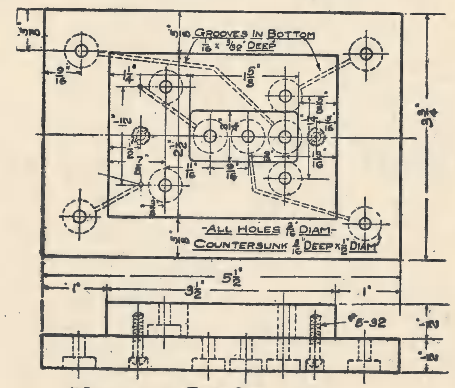


Figure 1

ment will give much better results for when the primary circuit is closed, your vibrator is ready to do its work. Below I will endeavor to instruct the experimenter how to make this instrument, and, if constructed as directed, it will be found to give a very good satisfaction.

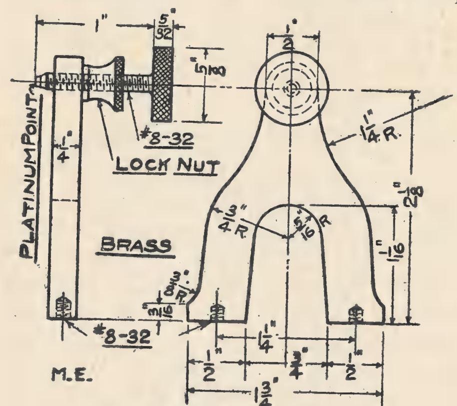
Obtain enough hard rubber ½ inch thick to make a base and sub-base, as shown in Fig. 2, which shows them held together by two No. 8/32 screws screwed into the top base. Hard wood may be substituted,

but hard rubber makes a much better base and gives a neater appearance. Four binding posts should be placed, one in each corner of the base.



-FIG 2-

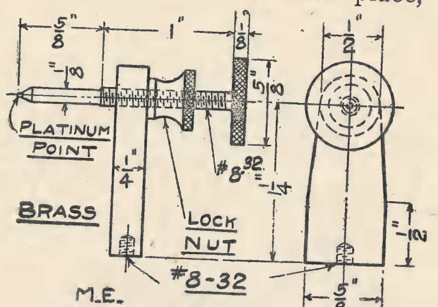
The two uprights shown in Fig. 3 and Fig. 4 are made of ¼ inch brass. The screws in the top of each



-FIG. 3-

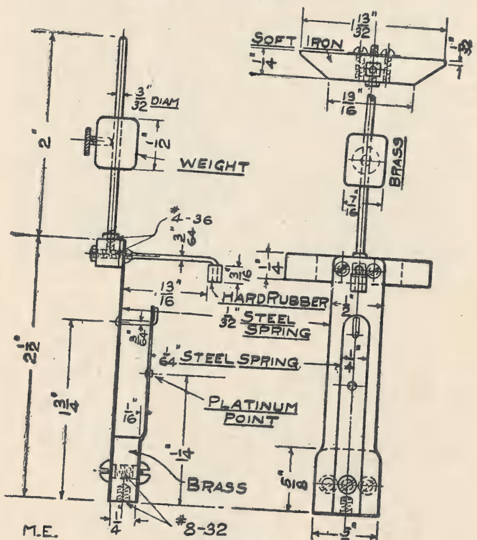
upright holding the platinum points are made of brass, having threads cut on each as shown. These

platinum points are soldered into place, the point



-FIG 4-

shown in Fig. 3 being about 3/32 inch diameter, while in Fig. 4 may be much smaller.



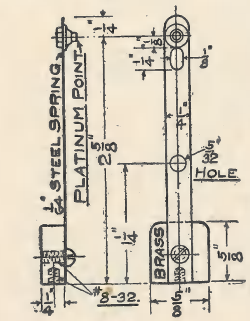
-FIG 5-

The armature and springs complete are shown in Fig. 5, the construction of which will be plainly un-

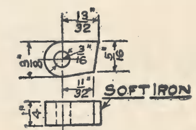
derstood by referring to drawing. The springs are made of spring steel, and the bottom bracket of brass. A small platinum rivet or point should be inserted in the small spring, as shown.

The primary circuit spring is shown in Fig. 6, and is made of spring steel, with the bottom bracket of brass. When drilling and filing holes in spring, as shown, care must be taken that the holes are the right size and in the right place. The platinum point in the top of this spring is held in place by soldering it in a brass cup, bolted to spring as shown.

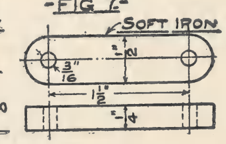
The electro magnets can be purchased from any



-FIG 6-



-FIG 7-

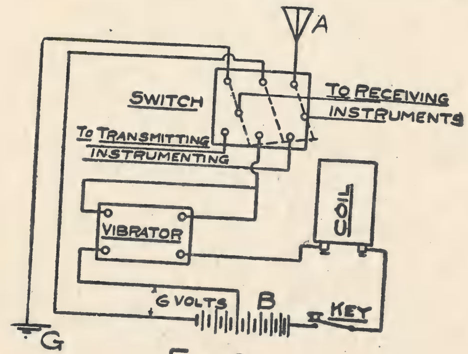


-FIG 8-

electrical supply house cheaper than they can be made. The figures in this article are to suit a pair of 4 ohm electromagnets purchased from a supply house. Tap a No. 8/32 hole in the top of each magnet core and make two magnet ends of soft iron, as shown in Fig. 7, which may be fastened to each electromagnet by a No. 8/32 screw. The magnets are spaced 1½ inches apart, and fastened to a piece of soft iron, such as shown in Fig. 8.

For the erection of this vibrator refer to Fig. 1 and connect up the instrument to correspond with grooves in the bottom base (Fig. 2), using No. 14 copper wire in connecting up the primary circuit.

If constructed as directed this vibrator will operate any coil up to 12 inches. Six volts will be enough to operate a pair of 4 ohm magnets, and if used in con-



-FIG 9-

nection with a coil having a core type of vibrator, screw up the vibrator screw so that it will not work, and wire as shown in Fig. 9.

SIMPLE WEHNELT INTERRUPTER.

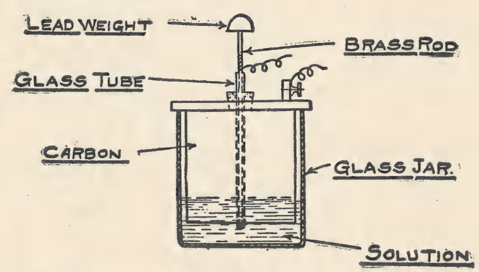
By D. ADAMS.

This interrupter is very simple and easy to make, but it will give as good results as those which are a good deal harder to make.

First procure an old battery jar and the carbon to fit it. This must be of the design shown in Fig. 1.

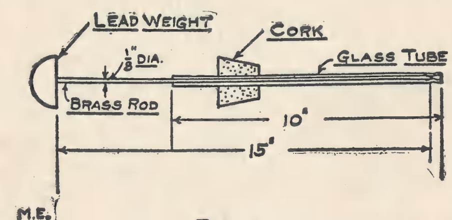
Next procure a brass rod, preferably ⅛ of an inch in diameter and about 15 inches long, and a piece of glass tubing having an inside diameter just large enough to admit the rod and about 10 inches long. Close the end of it by heating the end in a flame in such a way so that the brass rod cannot project past that end of the tube. Then get a cork large enough to fit into the hole in the top of the carbon. Bore a hole in the cork just large enough to admit the glass

tubing. Make this as snug a fit as possible so that the elevation of the tube in the jar may be adjusted. On top of the rod solder a lead weight. This automatically feeds the brass rod down as it is eaten away. The solution consists of 9 parts water and 1



M.E. -FIG.1-

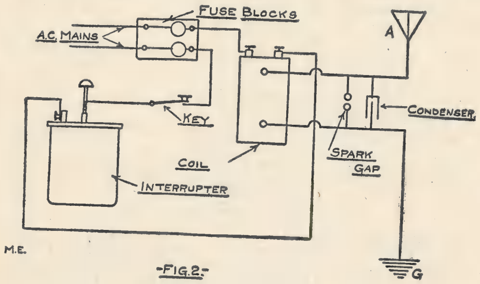
part sulphuric acid. Place enough of this in the jar to cover about one inch of the end of the carbon. Assemble the parts as shown in Fig. 1. You may make your spark stronger by raising the tube in the jar, but it is best to keep it about one inch from the bottom.



-FIG 1a.

tom. Keep the electrodes in your gap about ⅛ of an inch apart and you will get the best results. Connect up your set as shown in Fig. 2, winding the wire from the key about the brass rod (Fig. 2), and connect the wire from the primary of the coil to the screw on top

of the carbon. It is always best to use a fuse block as shown to prevent accidents to the interrupter.



-FIG.2-

This interrupter will do very satisfactory work on 110 V. A. C. Be sure to screw the vibrator down tight before using coil.

AN ADJUSTABLE IMPEDANCE COIL.

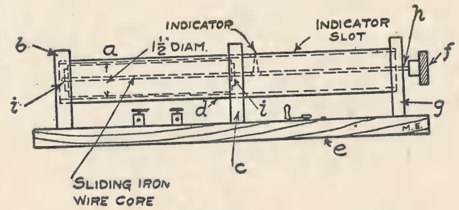
By Austin C. Lescarboura.

In compliance with numerous demands from experimenters who possess electrolytic interrupters, and cannot obtain the expected results from them, the writer has tried to explain below the construction of an effective device to remedy these failures.

An electrolytic interrupter connected in an inductance circuit is controlled by two factors, the point exposed (or size of opening as in the two jar type), and the amount of inductance in the circuit, these two regulating absolutely the frequency of the interruptions and the current flowing. Therefore, as the changing of the inductance in the circuit alone suffices to regulate the frequency, in non-adjustable types this method is applied and with gratifying results. The apparatus then necessary is a very gradual, variable, impedance coil such as described in the following paragraphs:

The writer was shown this form of choke coil by Mr. H. W. Secor. He was once called upon to examine an alternating current arc light in a moving picture projector, which consumed an amazing amount of current, besides burning very unsatisfactorily. After trying various forms of resistance and obtaining no satisfaction, he resorted to the apparatus herein described, which proved to be the "missing link" in the arc light episode, and saved the owner from further trouble. When this same apparatus was tried in connection with an electrolytic interrupter and a wireless transformer, it again distinguished itself by giving excellent results.

Procure a piece of oak or other hard wood 20 inches long by 6 inches wide and ¾ inch thick to serve for the base, e, Fig. 1, as shown in the diagram, for



-FIG. 1-

mounting the upright pieces, binding posts and switch.

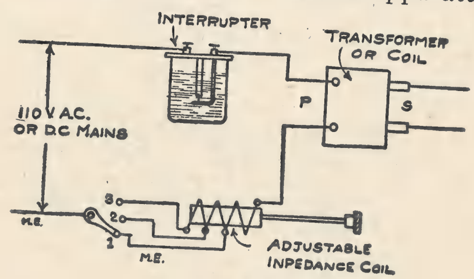
Have three upright pieces of wood, b, c and g, made as shown in sketch, and bore holes in these as required with an extension bit.

Purchase a fibre tube from an electrical supply house, 16 inches long, 1½ inches inside diameter, with wall 1/16 inch thick. With a small pointed saw or file, cut a slit 7 inches long by 1/16 inch wide, to act as a guide for the indicator.

Wind on the bobbin, a, three layers of No. 12 B. & S. cotton covered wire, carefully shellacing each layer. The winding should cover 8 inches of the tube length, and a tap should be taken from each layer, as

shown in the diagrams, and connected to the three-point switch, Fig. 3.

The sliding core should be made of soft iron core wire, No. 22, which is sold by electrical supply houses at a cost of about 20 cents per pound. Obtain three pounds of 8-inch core wire, also a brass rod 1/8 inch diameter by 17 inches long. Build the iron core 1 3/8 inches diameter around the brass rod. Tie plenty of cord around the core so as to firmly secure it in shape and solder it to the rod as illustrated. Place a small electrose handle on the end of the rod so as to insulate and improve the appearance of the apparatus, and a



-FIG. 3-

small indicator to protrude through the slot in the fiber tube.

After making the necessary connections to the binding posts and switch, the coil is ready for service.

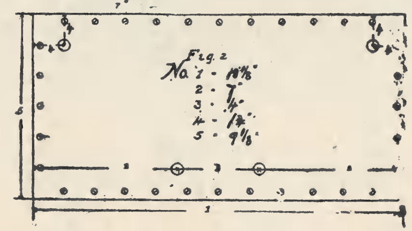
The coil when placed in series with an induction coil or transformer, and an electrolytic interrupter, will give a great variation in the frequency of the spark. By utilizing only one layer of wire, a very small amount of inductance is obtained. This apparatus can be used in all alternating current circuits for a variable choke coil, and as a ballast on direct current coils, and transformers up to 1½ K. W. All high efficiency commercial stations have a reactance regulator which is a form of choke coil, only it has a closed core.

A TESLA COIL.

By A. C. Austin, Jr.

The Tesla coil, shown in the illustrations was recently built for the purpose of experiment, and as many strange and beautiful effects may be obtained with it, the author will describe in detail the construction of the apparatus.

This particular coil, when used with a two-inch induction coil, and a condenser of four sheets of tinfoil 10x12 inches mounted on glass plates, gave a

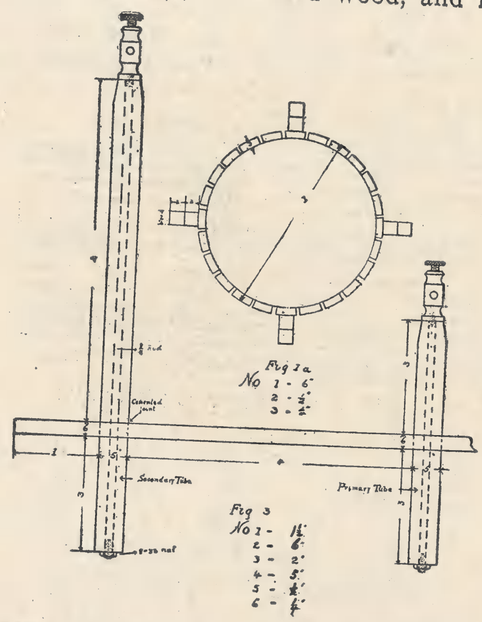


spark 4 to 6 inches long and in a darkened room there was a heavy brush discharge when the terminals were separated about eight or ten inches, and occasionally a single spark would pass even at this distance. At all times the secondary terminals, when the light in the room is turned down will have a luminous glow, and streams of light will be seen emanating from them in all directions, at times more intense than

usual, and particularly so when one of the secondary terminals is grounded. When the terminals are placed just beyond the distance at which sparks will pass, a great amount of ozone will be liberated.

The construction details of the coil in question are as follows:

Obtain, or make a case 18x9x9 inches, inside measurement, made of ¼-inch hard wood, and line same



with sheet zinc about 24 or 26 gauge, soldering at the joints, and being sure that they are liquid tight. One-quarter of an inch from the top of the case, place a strip ½ inch square all the way around the inside this forming a base to set the cover on and to screw same to, leaving a space about two inches long in the middle of each end for the supports of the coil to fit through.

Make a cylinder of wood 6 inches in diameter and 17 inches long. This cylinder may be built by nailing slats around several wood discs. On this cylinder after rounding the edges of the slats with a rasp, wind four hundred turns of No. 30 B. & S. gauge single cotton covered wire, beginning a little more than an inch from the end of the cylinder and winding the turns as accurately as possible 1/27 of an

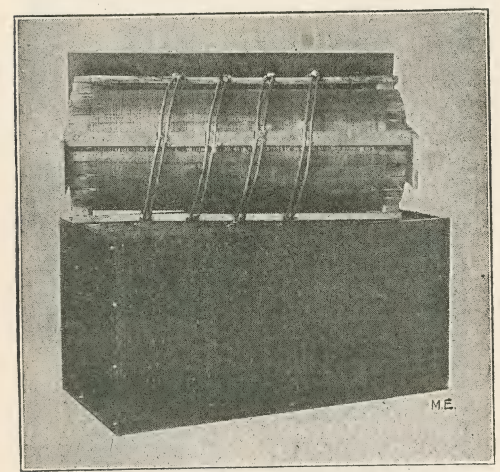


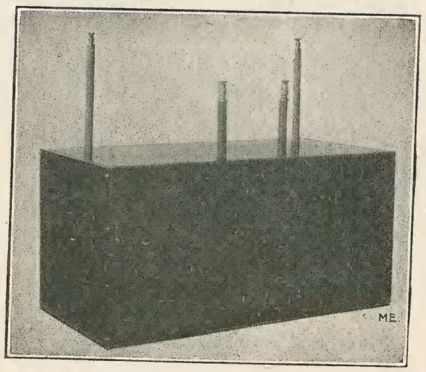
Figure 4

inch apart. Coat the cylinder and wire with shellac, giving some four or five coats, waiting until the first is dry before putting on the second, and so on.

Place four blocks of wood, ½x½x1 inch at equal distances from each other, on each end of the coil, so as to form supports for four sticks, ½x½x17 inches, running lengthwise on the coil and separated from the secondary wire, on which to wind the primary coil.

Now make two grooves ⅛ inch deep and ⅛ inch wide, making this measurement a trifle full and cut same a scant ¼ inch apart, the edge of the first groove

to be 3¼ inches from the end of the coil on the strip which is to be at the top of the coil when finished, and, turning the coil in the same direction as when winding the secondary, cut two grooves 3¾ inches from the end on the next stick, 4¼ inches on the next strip and coming back to the strip from which the start was made 5¼ inches from the end, making the last grooves just 2 inches away from the first ones cut, continuing on until enough grooves have been cut to wind four complete double turns of wire in. Procure about 30 feet of No. 6 B. & S. gauge soft drawn bare copper wire, and wind four double complete turns in the grooves, fastening same into the grooves by tieing with stout cord or twine. All of the preceding



Finished Coil

operations are clearly explained in Fig. 1, and also by the photographs, Figs. 4 and 5.

Obtain a sheet of hard rubber 18⅛x9⅛x¼ inches and trim to fit perfectly tight in the top of the transformer case. Drill the holes for screws around the edges and then drill a hole at each end ½ inch in diameter, the center of the hole to be 1¾ inches from the side and 1¾ inches from the end of the rubber

sheet as shown in Fig. 2. Also on the opposite edge of the rubber sheet drill two holes ½ inch in diameter 4 inches apart and each one 7 inches to center, from the end, as also shown in Fig. 2.

Insert in the first mentioned holes hard rubber tubes ½ inch in diameter, projecting 2 inches below the cover, and 6 inches above, fastening same tightly

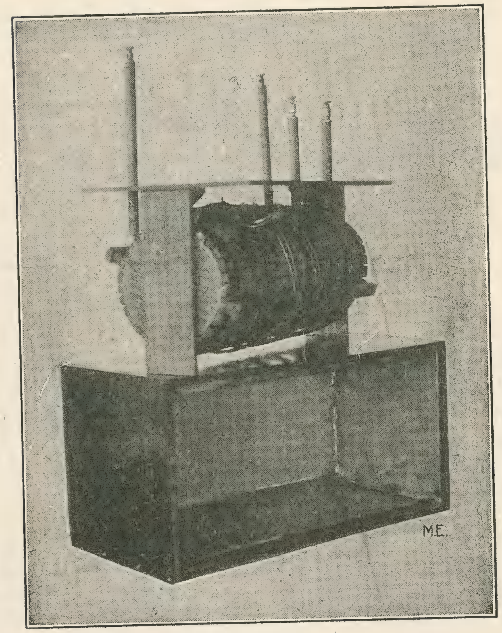


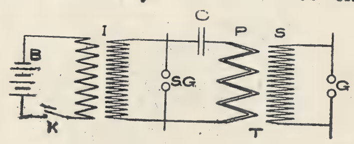
Figure 5

by cement (Fig. 3). The two other holes should be fitted with tubes of the same kind, projecting 2 inches both above and below. Now make four pieces of brass rod ¾ inch longer than the tubes, and put ½ inch of 8/32 thread on each end, and putting these rods through the tubes screw a binding post on the

top and a nut and washer on the bottom to clamp same into the tubes. The last operation is clearly shown by Fig. 3.

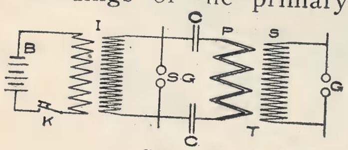
Now take the coil, and on each end place a standard of wood ½ inch thick, making a bracket shaped piece to fit the top of the standard, and projecting inwards, so that the rubber top may be screwed to these standards, and hold the coil suspended in the oil. The exact measurements and details of this operation cannot be given, and it will be necessary for the person building this coil to use the head a little bit, and simply make it fit. Photograph 5 will give a fairly clear idea of the method used by the author.

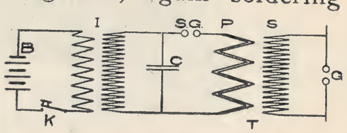
Connect the secondary terminals to the brass rods



"A"

running through the secondary tubes, soldering same tightly, being careful not to leave any slack wire, and running straight from the end of the winding to the rod, and not too close to either the primary winding or the zinc lining of the case. Now connect the two windings of the primary together, again soldering





"B" "C" M.E.

well, and making the windings in parallel, and then connect to the brass rods running through the primary tubes. This last operation is somewhat difficult and care must be taken not to make the single wire cross over too close, as one of the turns might short circuit.

Procure about five gallons of linseed or paraffine oil, and after boiling pour into the case while still warm, putting in enough to fill the case about ¾ full. Now lower the coil slowly and carefully into place, and just before screwing down the cover see that the oil comes up to about ½ inch from the cover. The placing of the coil into the oil while still warm drives all the air bubbles out, and diminishes the danger of the insulation breaking down. However, the oil must not be too warm when the coil is immersed, as the heat might melt the rubber tubes and cause the rubber top to warp.

A number of different methods of connection are shown by the diagrams "A," "B" and "C," and these may all be tried. The amateur using this coil will experience some difficulty in obtaining the right length of spark and the right capacity of the condenser, but when the right adjustment is found the coil will be found to work very satisfactorily. Of course with a larger induction coil, for instance a 3 or 4-inch coil the transformer will do a greater amount of work, but as before stated, a two-inch coil is used by the author. A smaller coil was tried but the result was very unsatisfactory.

This Tesla coil has been used both for experimental and for wireless work, and has given very satisfactory service.

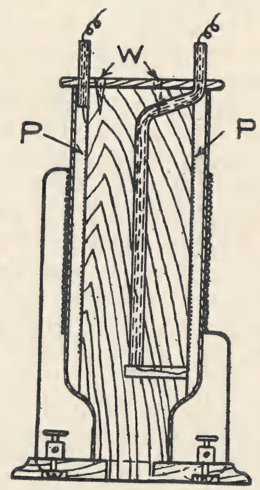
A TESLA DISRUPTIVE COIL.

By C. Clarence Whittaker.

The "Tesla" disruptive coil is a coil which increases both the tension and the frequency of the current of an ordinary induction coil. In the larger coils of this kind all insulating parts are made of hard rubber and the whole coil is immersed in paraffine or transformer oil.

In the coil which I will will here describe, hard rubber and oil will be replaced by glass and paraffine respect-

ively, as these are the next best substitutes. Fig. 1 shows a vertical cross section of this coil. The primary coil consists of about twenty-five turns of large rubber-covered wire, such as flexible lamp cord, wound in one layer. It is wound on a glass gas lamp chimney. The tube on to which the secondary is wound is made of some hard wood such as maple. It is highly important that this should be entirely free from all moisture. After it has been turned to the



-FIG. 1-

proper dimensions it must be dried in a hot oven, after which it should be thoroughly soaked in boiling paraffine. This will render it entirely impervious to moisture. The secondary is wound on to this and consists of one layer of No. 32 or 33 D. C. C. copper wire. The ends of this layer should extend about an inch beyond those of the primary layer. It will be seen from the illustration that the relative position of the secondary and primary coils is the reverse of

that in an induction coil; that is, the secondary lies within the primary. The upper terminal of the secondary is brought directly to the top through a glass tube; the lower terminal, on account of the great difference of potential existing between these two ends, must be brought to the top by leading it through another glass tube, which has been fitted to a hole drilled lengthwise in the wooden form and to a shallow slot nearly perpendicular to this hole.

The base is attached to the hard-wood form, as shown in illustration, and contains two binding posts to which are led the terminals of the primary.

The whole coil should now be warmed so that when the molten paraffine P is poured between the outer glass and the secondary, no fractures will occur. Enough paraffine must be poured in to completely fill the glass. After this has cooled, a thin wooden top, previously boiled in paraffine, may be fitted around the terminal tubes and attached to the hard-wood form by means of wooden plugs W W. These secondary terminals should be situated as far distant as possible, as the brush discharge from this current is very marked. The connections are shown in Fig. A, B, C, page 38.

The primary of this coil may be thought of as analogous to the antennae of a wireless station which is transmitting, and the secondary as analogous to one receiving. In regarding the coil in this light, the value of condensers coupled to the spark of the transmitting apparatus in wireless telegraphy is clearly shown by the following: When the condenser C is not used with the coil, only a small current is noticeable at the disruptive terminals; but when the condenser is attached, as in Fig. A, B, C, a multitude of high tension discharges occur.

However paradoxical it may seem that this disruptive discharge is of so high a tension and frequency that no perceptible shock can be obtained from it, it

is nevertheless true. The slight burning sensation which is experienced when the current is passed through the body when contact is made with the bare hands vanishes when contact is made with metallic objects held firmly in the hands, on account of the greater surface offered by these electrodes.

With this current, exhausted tubes may be made to glow brightly, but differently from those operated by an ordinary induction coil. Both terminals in the tube exhibit the same brightness on account of the condenser in the circuit, which tends to make each alternation of the current of equal moment.

AIR-INSULATED TESLA COILS.

A Tesla coil suitable for use with spark coils of from 2 to 6" spark, with air as an insulator, may be made as follows: On a paper tube 3" in diameter and 11" long, wind 1 layer of No. 31 B. & S. enamel wire.

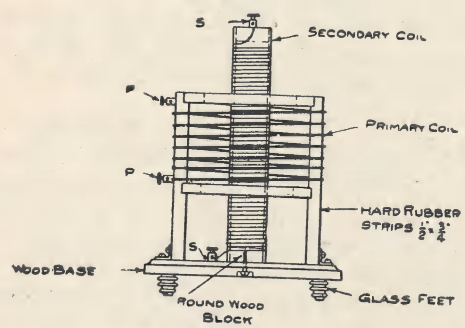


Figure 1

This is the secondary and is supported as shown in Fig. 1.

The primary is formed of 20 turns No. 14 B. & S. solid or better stranded copper wire, rubber covered,

wound on a paper or hard rubber tube 6" in diameter and 6" long. This coil if properly used, will give 3" high frequency sparks, between its secondary terminals, when operated by a good 2" spark coil, and a glass plate condenser made of 12 plates, 8"x10" coated

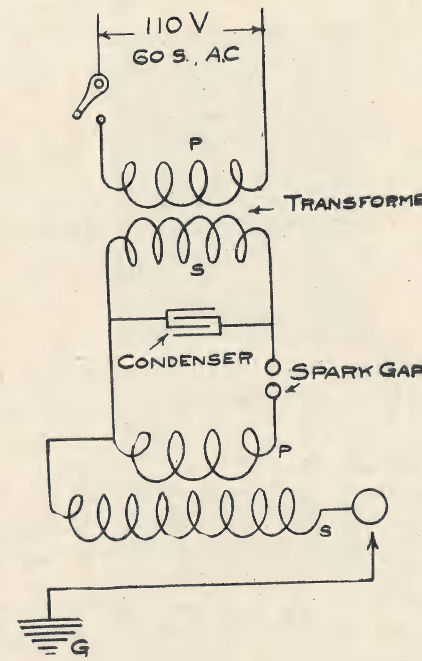


Figure 2

with tinfoil on both sides 6"x8". The spark gap must be adjusted very carefully also use a different number of condenser plates until the maximum efficiency is attained.

To make an Oudin resonator out of this coil, drop the primary coil down to the bottom of the sec-

ondary, and wind secondary with wire 1 or 2 sizes smaller. Connect the bottom of the primary with the bottom of the secondary, as shown in Fig. 2.

A Tesla coil which may be run by a ½ K. W. transformer, can be constructed along the following lines. Make the secondary of 1 layer of No. 27 B. & S. enamel wire, spacing the turns the thickness of No. 27 wire apart, on a paper tube 6″ in diameter and 20″ long. The primary may consist of 15 turns No. 6 aluminum wire wound on a tube or drum 12″ in diameter and 8″ long, spacing the turns ½″ apart. The coils should be supported as shown in Fig. 1. The condenser may be the regular ½ K. W. condenser, made of glass plates. The spark gap, condenser and primary clips should be adjusted simultaneously until the desired results are obtained. This Tesla coil may also be operated by a 12-14″ Induction coil.

A LARGE DEMONSTRATION TESLA COIL.

A large Tesla coil, such as used for electrical demonstrations on the stage, lectures, etc., may be constructed at small cost, and can be operated by a ¾-1 K. W. transformer, or 18″-20″ spark coil.

Make up a secondary drum 11″ in diameter and 45″ long. A primary drum or cage 10″ long by 22″ in diameter. Wind on the secondary drum, 1 layer of No. 25 enamel wire, spacing the turns apart the thickness of No. 24 wire; on the primary wind 10 turns, spaced ¾″ apart of No. 4 aluminum wire. This coil will give sparks 3 feet long, when properly operated.

EXPERIMENTING WITH THE TESLA COIL.

By H. Gernsback.

There seems to be a general dearth of matter on this subject. This is not surprising when we bear the fact

in mind that literature on Tesla high frequency currents is very scarce indeed. The few books treating upon the subject are so purely technical that the average experimenter gets hopelessly entangled in his efforts to plow through the maze of theories, foot-notes and technicalities, useful only to the hardened scientist.

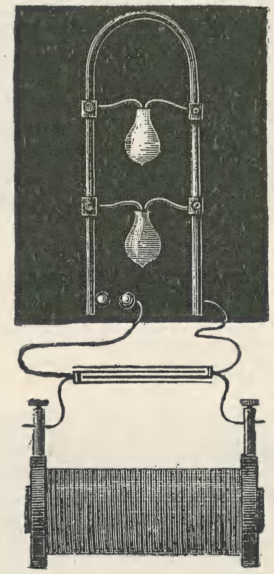


Figure 1

The scope of the present article is to make the experimenter and amateur more fully acquainted with the wonderful high frequency currents, without indulging too much in theory, so thoroughly hated by the young experimenter.

Any of the experiments described in this article can be carried out with the Tesla coils described elsewhere in this book.

In some of the illustrations in this chapter a coil resembling a common induction coil is shown for simplicity's sake, but it is of course understood that same stands for the Tesla coil, as none of the experiments can be performed with a spark coil alone, no matter how large.

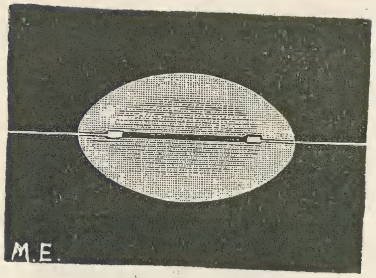


Figure 2

Although the potential of a well constructed Tesla coil runs up into hundred thousands of volts, such currents, as explained elsewhere, are harmless to the human body. For this reason experiments with such currents are less dangerous than those made with even a three-inch spark coil.

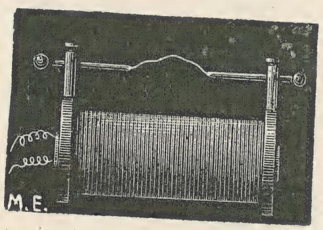


Figure 3

Possibly the most puzzling experiment to the individual acquainted only with low tension work is the phenomenon of the impedance. The meaning of this word is "seeming resistance." If we short-circuit an electric lamp by means of a heavy wire, we would hardly expect that we could light up the lamp thus short-circuited, under ordinary circumstances. By means of Tesla currents, however, we can light up several lamps, despite their being shorted with a heavy (No. 8 or 9) wire.

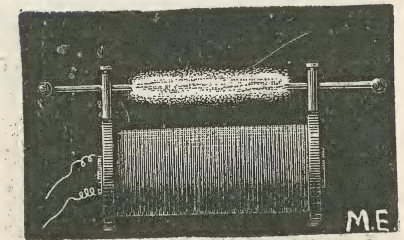


Figure 4

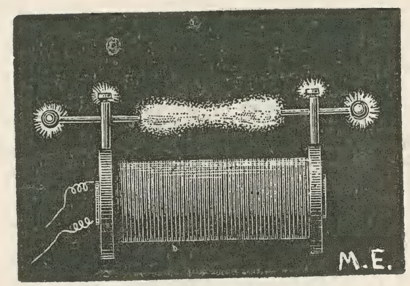


Figure 5

The arrangement is shown in Fig. 1. One or more 50-volt lamps are made to slide up and down on a

heavy copper wire loop. This loop is connected on one side to the Tesla coil, bridged by a large condenser (Leyden jar). The other wire from the condenser terminates at a brass ball. Another similar

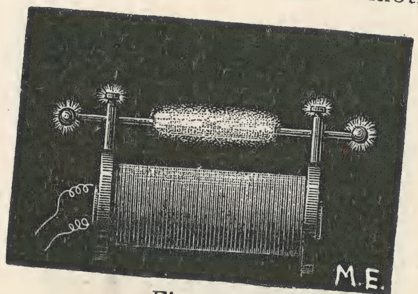


Figure 6

ball is placed opposite the first one and is connected to the wire loop.

In operation intense white sparks jump between the balls. By moving the lamps up and down the loop,

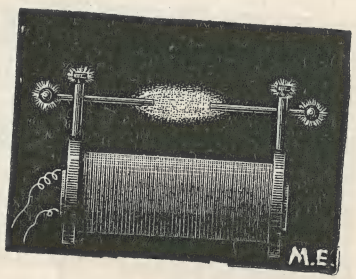


Figure 7

the highest degree of incandescence is quickly ascertained.

Experiments with the impedance will come out best when the wire of the loop is very heavy. A copper

rod even ½ inch thick bent into shape as shown in Fig. 1 will give excellent results.

Another interesting experiment with the impedance

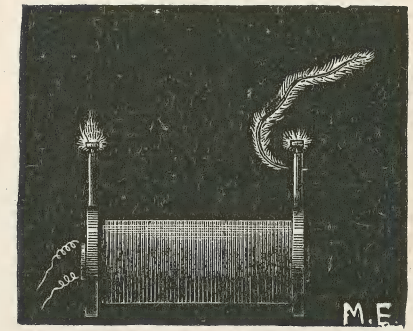


Figure 8

is shown in Fig. 2. It represents an ordinary incandescent lamp having a straight filament. One would be led to think that the current would take its way

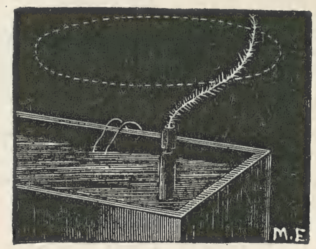


Figure 9

from terminal to terminal. Under certain conditions, however, the carbon filament stays black, and sparks jump from one terminal to the other, as if the filament was not there at all, or as if it were an insulator.

In operation, five typical forms of discharges are observed with the Tesla coil. If we use little current (amperage) in the primary circuit, we obtain a thin light thread between two sharp points (Fig. 3). This thread is extremely sensitive and will change its position if one breathes lightly from a little distance. The slightest draft in a room causes the thread of light to flicker violently.

If we increase the amperage up to a certain extent, we produce the flame discharge (Fig. 4). This flame is capable of radiating quite a good deal of heat, and the noise produced by the flame is little; much less, in fact, than the spark discharge of a one-inch coil.

The previous two experiments could not be strictly termed as high frequency ones, as the alternations were comparatively low. If we increase the current still more we obtain the high frequency arc discharge. Same is characterized by the brush discharge which takes place on all the metal terminals (Fig. 5). The arc produces a good deal of ozone, which makes itself known by a peculiar, but pleasant and invigorating, odor.

By further increasing the amperage and by separating the discharging rods but little, we obtain a peculiar spark discharge composed of extremely thin, blinding, white threads enclosed in a large flame or spray (Fig. 6). This discharge is the most beautiful; it can be further intensified by using a strong air current trained against the spray. Sparks can be made to fly off similar to those produced by sharpening a metal tool on a grindstone. These electric sparks, when blown on the experimenter's skin, produce a rather unpleasant sensation, but are quite harmless.

Fig. 7 shows the fifth typical form of discharge. When the current is increased to its maximum, and when the oscillations have reached their highest value,

it is quite hard to confine the charge to the discharging rods. It is neither easy to obtain a spark discharge; and if produced at all it will only take place when the rods are quite close together.

A short piece of thin, cotton covered copper wire

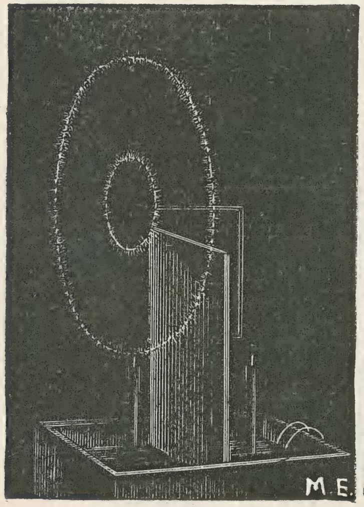


Figure 10

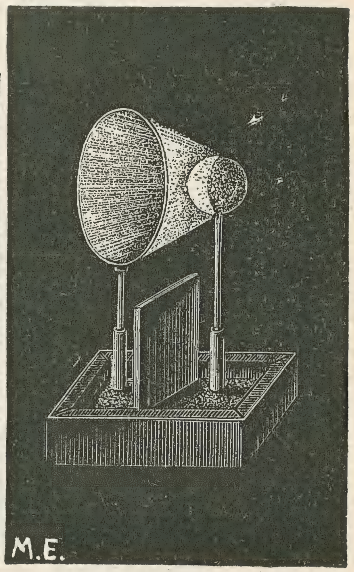


Figure 11

when attached to one end of the coil is enveloped in a beautiful light discharge (Fig. 8).

Fig. 9 shows another interesting experiment which, when produced in the dark, is quite impressive. A very thin, bare copper wire attached to one end of the coil, rotates in a circle. The length of the bare wire must be ascertained by experiment.

Two rings formed of copper wire, the smaller ring

placed into the larger one, and both connected to the poles of the coil, will show a very pretty discharge (Fig. 10).

By concentrating the effect the intensity of the light is greatly increased as shown in Fig 11.

A circle of copper wire is made, which is connected to one pole. The other pole carries a brass ball, its diameter being approximately ¼ of that of the circle. As soon as the coil is started, the discharge takes place between the surface of the brass ball and the rim of the circle. A hollow cone of light is formed, presenting a weird appearance.

ELECTRICAL STARS.

By H. Gernsback.

It is surprising to find that almost every other amateur or experimenter never saw or heard of the wonders of a revolving Geissler tube, producing the marvelous electrical stars, although he has in his possession all the apparatus needed to produce them.

The majority of our readers are well acquainted with the Geissler tube, but to most of them, possibly, the thought never occurred to revolve a tube at high speed while in operation. At first thought we would be led to believe that a revolving tube would not look any different than one at rest, which is possibly the reason that very few try the experiment, but let them "discover" it and they will sit for hours in front of a silently revolving tube, watching the ever-changing stars.

When a tube is made to revolve at high speed and the vibrator of the spark coil works very fast, we see a luminous circle of various colors, depending of course on the natural colors of the tube. As the tube is revolving too fast, the eye cannot follow it,

and the consequence is that the colors "mix" or mingle producing new colors and new effects. This is especially true of the Geissler tube containing fluorescent liquids.

If we now screw the coil vibrator back, (slowing down its speed) we will at a certain point find that we have a seemingly slow revolving star which may have 8 to 16 corners. If the speed of the vibrator is reduced still further, we can get a 4 or 8 cornered star which is "standing still" despite the fact that the tube is revolving at high speed. The strangest part, however, is that sometimes while we look on the

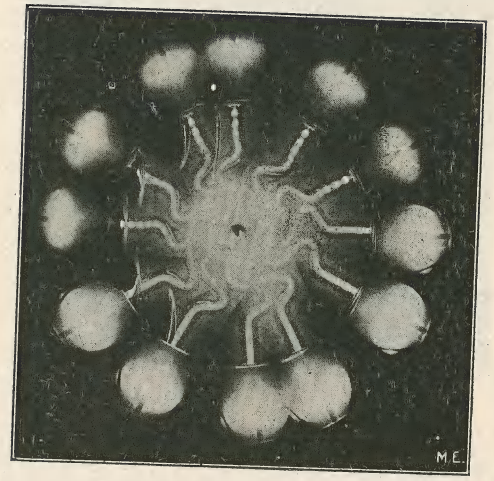


Figure 1

direction of the star is reversed, revolving in the opposite direction of that of the motor.

To understand how this is brought about, we have to remember that the current of a spark coil passing through the tube is not continuous, but is interrupted

all the time by the interruptions of the vibrator. While the tube is at rest we fail to observe these interruptions, as they are too fast for our eye to follow. It is the same with an electric bell; the clapper of same is striking so fast that our ear cannot hear each stroke, and a continuous sound is the result.

In the rotating tube we are made to see the interruptions, as if for instance four interruptions occur

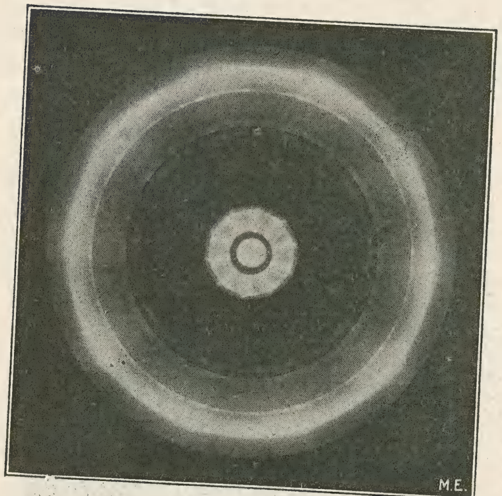


Figure 2

while the tube has turned around once, we must of course see four tubes at practically the same time. Therefore, if there are four interruptions to one revolution we see an 8-cornered star (each tube having two ends). If we have eight interruptions we shall see a 16-cornered star, and so on.

If the interruptions of the vibrator per second are less fast than the revolutions of the tube per second, the star will obviously turn backward.

If the speed of the tube and that of the vibrator is the same the star will stand still (Fig. 1). Fig. 2 shows the tube as it appears under very fast vibrations. The photographs, however, cannot do the tubes justice, as we cannot take an instantaneous photograph on account of the weakness of the light of the tube.

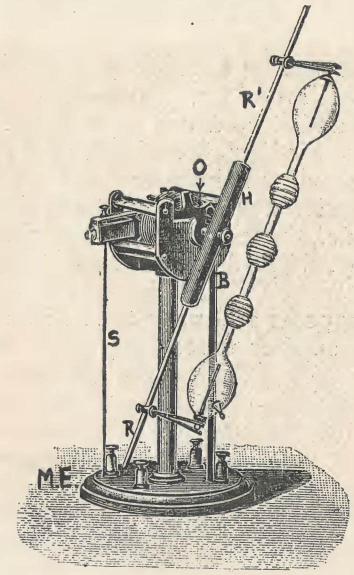


Figure 4

As for the apparatus to revolve the tube, an ordinary small battery motor, raised, so that the tube does not touch the table, is used (Fig. 3).

The axle of the armature should be lengthened to allow a rubber disc O of about one inch diameter to be fastened on same. This disc has a groove around its circumference so that a copper wire can be laid

in it. A brass strip B is made to rest against the rubber disc so that it keeps contact with the copper wire while the armature revolves the disc.

A hard rubber tube H is also forced on the axle, and two brass rods R and R′ are fastened by means of shellac in the tube. It is important that the rods fit tight. R goes all the way through the tube to touch the axle. R′ does not reach the axle and should be about ½ inch away from same. A thin wire from R′ goes to the rubber disc and is fastened to the copper wire in the groove. S goes to a spring to make contact with the axle. The coil current is led to the posts of S and B, and will operate the tube. The remaining two binding posts belong to the motor proper, which revolves the tube.

The high tension current from the coil flows thus: From S to axle, thence to R, passes the tube, goes to R″, wire in rubber disc O, brass strip B, back to coil.

Two binding posts are made to slide on the rods to take larger or smaller tubes.

CHAPTER IV.

THE HIGH TENSION TRANSFORMER.

By M. A. Deviny.

The high tension alternating current transformer for producing exceedingly high potentials from a low potential source of supply has been so perfected in recent years that it is now rivaling the induction coil for general experimental purposes, and, owing to the many marked advantages possessed by it over the ordinary type of induction coil, it is rapidly supplanting the latter in nearly all of the high powered long distance wireless telegraph stations. The reasons for this substitution are many; it being chiefly due to the extreme simplicity, high efficiency and the possibility of construction so as to obtain large outputs —three very important factors in connection with long distance commercial transmission — which are possessed by the transformer.

The principle upon which the device operates is, no doubt, familiar to the majority of the readers of this book, but, as is the case of all electromagnetic appliances, a thorough understanding of its action can only be obtained by a complete mathematical analysis of the considerations involved, but for the benefit of those who have not studied the subject, a brief summary of the general operating principles may be of interest.

The transformer in its simplest form consists primarily of two electrically independent coils of insulated wire, of any desired number of turns, which are wound upon a closed iron ring in the manner shown

in Fig. 1. If a key and a battery be connected in circuit with the primary coil P, and the terminals of the secondary coil, S, be connected to a galvanometer, a momentary deflection of the galvanometer needle will be observed when the key K is depressed, while on releasing it and opening the circuit, a deflection in the opposite direction will be observed. This example of electro-magnetic induction may be explained as follows:

When the primary circuit is closed by depressing the key, the battery current in passing through the coil P strongly magnetizing the core C, setting up in it a magnetic flux which, in traversing the core, necessarily passes through the coil S. The sudden introduction of the magnetic lines of force into S induces in it an electro-motive force, which, when

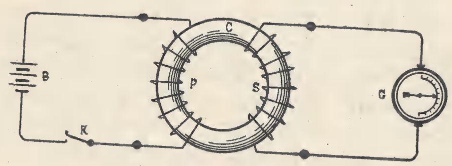


Figure 1

the circuit is closed through the galvanometer, gives rise to a momentary current in it, thus causing a deflection of the needle. When the key K is released, however, the primary current ceases to flow and the magnetism of the core vanishes; the sudden withdrawal of the lines of force from the secondary induces in it an electro-motive force which will be of opposite polarity to that produced when the circuit was closed, and hence the current produced will flow in the opposite direction through the galvanometer and thereby causing a reverse deflection.

From this it is evident that if some means were provided for continually making and breaking the primary circuit a sustained alternating current could be obtained from the secondary winding. This is exactly the purpose of the interrupter in the primary circuit of the ordinary induction coil which, when no condenser is shunted across the vibrator terminals, delivers a true alternating current when the secondary circuit is closed. If instead of employing an interrupter, we were to connect the terminals of the primary coil P directly across the line supplying an alternating current of the proper voltage and frequency as is shown in Fig. 2, the variations in the

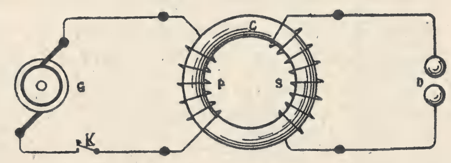


Figure 2

magnitude of the current through the various portions of the cycle will cause corresponding variations in the magnetic flux produced in the core with a consequent variable induced electro-motive force in the secondary.

The magnitude of the E. M. F. so induced in S will be dependent upon the amount of magnetism produced by the primary, which in turn will be dependent up the strength of the primary current, and the E. M. F. will also depend upon the number of turns composing the secondary. By increasing the number of turns in S the value of the induced electro-motive-force may be made anything desired so long as sufficient insu-

lation is provided and it will be found that the ratio existing between the number of turns in P and those comprising S is exactly equal to the ratio of the electro-motive-forces of the two circuits. Thus for example, if it is desired to raise the potential of a 100-volt circuit to 1,000 volts, it is necessary that the secondary coil of the transformer employed shall have exactly ten times the number of turns as the primary coil. But in having ten times the number of turns, the secondary will also have ten times as much resistance and hence the current in S will be only one-tenth of that in P. Thus it can be seen that the current in each of the coils is inversely proportional to their voltages and hence the energy of the two circuits—neglecting the losses in transformation—is equal, these principles being applicable whether the transformer is used to raise or to lower the voltage of the supply.

If the cores of transformers were made of a solid ring of iron as is indicated in Fig. 2, the current in the primary coil would induce in it an electro-motive-force for the same reasons that one is induced in the secondary coil and, although of small value, this would give rise to very large currents in it due to the exceedingly low resistance of the comparatively large mass of iron. This would cause the core to heat and thus greatly reduce the efficiency of the device. In order to reduce these "circulating" or "eddy" currents, as they are called, the cores of all transformers are invariably made up of very thin sheets of soft iron which are carefully insulated from each other and built up like the leaves of a book. The insulation between these "laminae" consists usually of a coat of some good insulating varnish or shellac and as the difference of potential between them is exceedingly small, this insulation is generally more than sufficient. This form of construction

reduces the loss by eddy currents to such an extent as to render it almost negligible.

On account of the difficulty of winding the wire on a circular magnetic circuit the cores of transformers are usually made rectangular in form, the coils being form-wound and placed over two opposite sides of the rectangle after which the cores are then bolted together in the manner shown in Fig. 3. In commercial transformers, where maximum efficiency is of extreme importance one-half of each of the primary and secondary coils is usually wound upon each limb, they being placed over each other and carefully in-

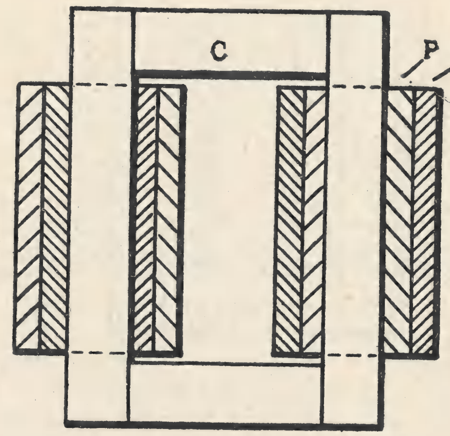


Figure 3

sulated. The order of the primary and the secondary is also reversed upon each of the limbs, that is, on one limb the primary is put next to the core and the secondary placed over it, while on the other limb the

secondary is placed next to the core and the primary placed on top of it. This distribution of the two windings is for the purpose of reducing the leakage of the magnet flux around the cores to a minimum and thereby causes all of it that is produced by the primary to be utilized to advantage in generating electro-motive forces in the secondary.

The continual reversal of the polarity of the magnetism in the core of a transformer causes it to heat considerably unless special precautions be taken

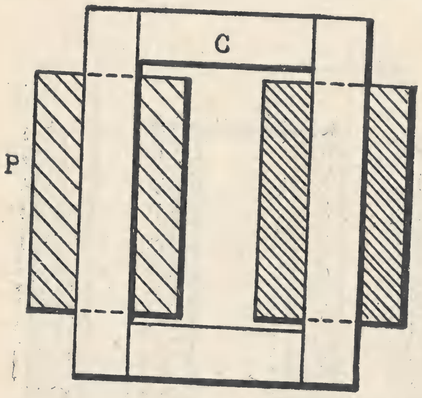


Figure 4

against it. This is due to the friction between the molecules of the iron constituting the core and is known as "hysteresis," or magnetic friction. It is dependent upon the quality of the iron used in making the core and to the degree of magnetization produced by the current, and it can only be reduced by using a core of large cross-section and by employing the softest grade of iron that is obtainable.

The action of the alternating current transformer under varying conditions of load is most remarkable. The primary coil is often of very low ohmic resistance and yet when it is connected across a comparatively high voltage source of supply practically no current will flow into it so long as the terminals of the secondary are left open. As soon as a load is put upon the secondary, however, current will flow into it, the amount depending entirely upon the current demanded by the secondary load. This is due to the following causes:

When the primary circuit is closed (Fig. 2), the alternating current rushes into it, thereby producing a magnetic flux in C which oscillates in unison with the changes in the value of the current throughout the different portions of the cycle. This flux, while generating an electro-motive-force, in S, must, in traversing the core, necessarily also pass through the primary P and in doing so it generates an E. M. F. also in the latter. But this electro-motive force is directly opposed to that impressed upon P from the line and when S is open it is nearly equal to it. Hence the current taken by P under these conditions will be dependent upon the difference between the E. M. F. of the line and the counter E. M. F. or the self induction of P itself, and therefore it will be of very small value. If, however, a load consisting of some lamps or motors be connected to the secondary a current will flow through it which will tend also to magnetize the core just the same as P, but the magnetism so produced will be in opposition to that produced by the primary and hence the latter will be reduced slightly in value. This reduction will diminish the number of magnetic lines of force passing through P and the opposing or counter E. M. F. will therefore drop slightly, thereby causing the difference between it and the impressed E. M. F. from

the line to become greater, which will in turn increase the value of the E. M. F. which is effective in producing the current in P, and in this manner the more current taken by S the greater will be the amount that will flow into P.

In transformers designed for high potential work thorough insulation is a very important factor and designers aim to make this feature as perfect as possible. The coils are very carefully insulated from the cores and from each other and in order to render the insulation still more efficient the entire transformer is placed in an iron tank which is then filled with some good insulating mineral oil. The oil, while greatly improving the insulation covering the wire, is of great advantage in several other respects. It possesses the very desirable and important property of automatically sealing any puncture in the ordinary insulation which might occur and at the same time also provides a most efficient method of cooling the smaller sized transformers by thermal convection.

In high tension transformers for experimental use and for wireless telegraph work, where extremely high efficiency is of secondary importance, the coils are wound in sections and are often mounted separately on each of the two main limbs of the core after the manner shown in Fig. 4. This is done in order to further improve the insulation and to render the two circuits mechanically independent and thereby greatly facilitating repairs when necessary. Such transformers, however, are never wound to produce such high voltage as those commonly obtained from induction coils of equal output and therefore the spark obtained from them is never very long. From fifteen to forty thousand volts is the usual secondary potential for which the secondaries of wireless telegraph transformers are wound. In some in-

stances this is increased to as high as 60,000 volts, but in many of the smaller transformers even 10,000 volts is sometimes employed. The spark obtained is very short, but as the resistance of the secondary is exceedingly low when compared to the resistance of the secondary of an induction coil of the same capacity, the current obtained is relatively very large and the spark that it produces is thick and hot, thus rendering it of great advantage for wireless transmission. These transformers are never rated by the length of the secondary spark but their output is always expressed in kilowatts as in the case with commercial transformers.

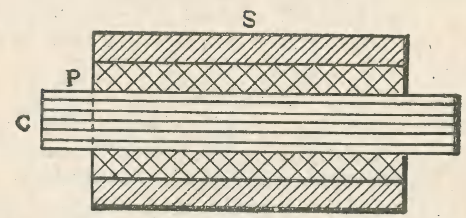


Figure 5

The high tension transformer requires but very little care and attention after it has once been installed and owing to its simple and rugged construction and the absence of all interrupters and other delicate and troublesome adjuncts there is practically nothing to it to get out of order and cause annoyance. On the other hand, they are exceedingly dangerous and must be handled with the greatest of caution, as a shock caused by contact with the secondary of even those of the smallest sizes will very frequently prove fatal. This is due to the comparatively large current which is delivered by the second-

ary and for this reason extreme care must be exercised in handling them when in operation.

The high efficiency of the transformer as compared to the induction coil is largely due to the closed magnetic circuit upon which its coils are wound. This forms a path of very low reluctance with the result that a smaller amount of current is required to produce the same number of lines of force than when the open core, such as is necessary with induction coils is used. However, some forms of transformers for wireless telegraph purposes have been designed in which an open core such as shown in Fig. 5 was used, and at one time this type was specified and used by the Bureau of Equipment of the Navy Department. No material advantage is gained by their use, and owing to the higher efficiency of the closed core type of construction it is still by far the most widely used form.

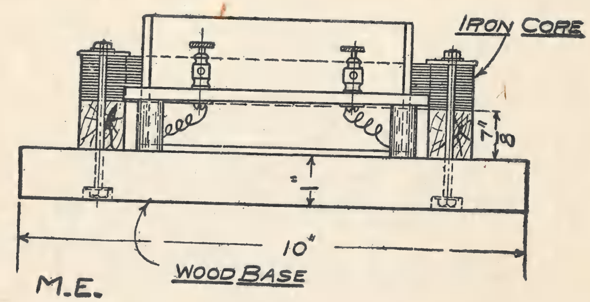
In view of the large current obtainable from the transformer, together with its high efficiency it has displaced the induction coil in nearly all commercial ship and shore stations capable of sending 100 miles or more. It is also considerably used by experimental stations sending below this distance and there can be but little doubt that the near future will see it installed in many amateur stations of moderate power.

250-WATT CLOSED CORE TRANSFORMER.

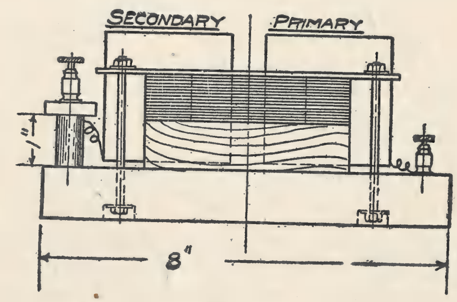
By Carleton Haigis.

This transformer is designed to operate direct from 100-110 volt alternating current supply and with suitable sending instruments and an 80-foot antenna will send 30 miles overland and a much greater distance over water, and can be rated at ¼ K. W.

For the core that of an old lighting transformer could be used, but in the absence of that, sheet stove-pipe iron of the dimensions shown at Figs. 1, 2, 3 and 4

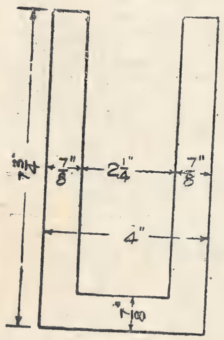


is very satisfactory. Enough of each size should be made to make a pile 7/16 inch thick, when pressed tightly together. These are easily cut out with a

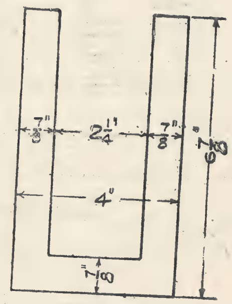


pair of tinner's shears and the rough edges should be smoothered with a file. Now, beginning with one of the pieces with the longer leg on the bottom place

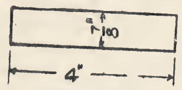
one with a shorter leg on top and continue alternately intermeshing them until you have them all assembled. They should make a pile ⅞ inch thick, and each



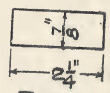
-FIG. 1-



-FIG. 2-



-FIG. 3-



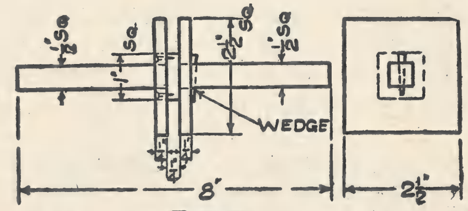
-FIG. 4-

M.E.

leg should be ⅞ inch square. The pieces in Figs. 3 and 4 are to be intermeshed between the openings left between the U-shaped pieces at the open end after the coils are in place.

Now we come to the hardest part in the whole construction—that of making the secondary sections. For this purpose a special winder will have to be made as follows: Having obtained a square piece of wood 1x1x8 inches, proceed to cut down the ends to the dimensions shown at Fig. 5, making the mandrel ½ inch square at the ends. Now, cut 2 pieces of wood ¼ inch thick and 2½ inches square and

make a ½ inch square hole in the center of each. One of these should be screwed permanently to the shank of the mandrel, as in Fig. 5, and the other should be secured in place by a pin passing through it so as to be able to remove the coils after they are wound.

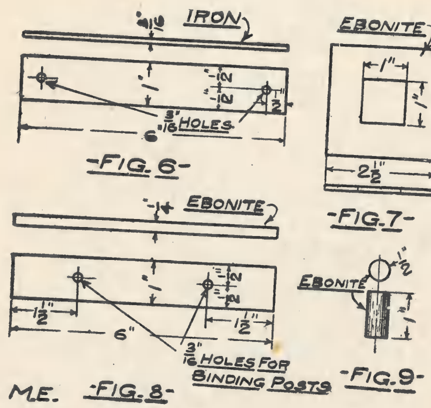


M.E. -FIG. 5-

Obtain a quantity of filter paper (such paper may be obtained at any druggist's) and from it cut 40 sections 2½ inches square with a hole 1 inch square in center. Each of these sheets should be paraffined with a good quality of paraffine. After they are dry place two of them on the mandrel and secure the movable piece in place. The whole should now be placed in a lathe or other suitable appliance for winding.

Procure 3 pounds of No. 31 single cotton covered copper wire (B. & S. gauge). Since all cotton has considerable moisture in it, the wire should all be dried in an oven the temperature of which should not exceed 100 degrees, as temperatures above this tend to carbonize the insulation. After the wire is dry wind 1,250 turns on the mandrel between the two sheets of paraffined paper. The wire must also pass through a dish of melted parraffine as it passes

onto the mandrel. After the section is wound it should be removed, and in this manner 20 such sections should be made. After these are completed paraffine enough filter paper 6 inches wide to cover one leg of the core 1/16 inch deep. This should be placed on the core while still warm, so as to make the paraffine hold it in place. Now, make two ebonite pieces 2½ inches square and ⅛ inch thick, with a 1 inch square hole in center (Fig. 7), and after having placed one on the core proceed to assemble the other secondary section upon it, and after all



are in place, the other ebonite piece. Now they should all be connected, care being taken that the current will flow through each in the *same direction*. The connections should all be soldered with a non-corrosive soldering fluid and wire solder by means of a small alcohol lamp. The two end terminals should be connected to heavier wires (about No. 18) and tied together temporarily.

On the other leg of the core wind 1800 turns of No. 16 S. C. C. wire, having bound a strip of paper around the core first. These terminals should also be tied together. Now we are ready to place the rest of the core in its place at the open end; these pieces (Figs. 3 and 4) will be found to go into the places left by the longer and shorter legs. After they are all in place a ⅛ inch hole should be bored in the 4 corners and a small bolt inserted. The sections should thus be securely bolted together. All that now remains is to mount the transformer on a suitable baseboard of any hard wood 10x8 inches and 1 inch thick. Make 4 cubical blocks 1 inch on a side and place one of them under each corner of the core. Obtain 2 pieces of iron 3/16 inch thick, 1 inch wide and 6 inches long and bore a 3/16 inch hole ½ inch from each end (Fig. 6). One of these should be placed across each end of the core and by means of bolts passing down through the holes into the base secure the whole firmly to the baseboard. Now get a piece of ebonite ¼ inch thick, 1 inch wide and 6 inches long. Two large binding posts should be placed 1½ inches from each end (Fig. 8) and the whole supported on 2 ebonite rods 1 inch high and ½ inch in diameter (Fig. 9), which in turn are fixed to the base. The two secondary terminals are now connected to the two binding posts supported on the ebonite and the primary terminals are also connected to two binding posts which pass directly through the base.

The primary is to be connected in series with an ordinary telegraph key direct to the 100 volt alternating current and should develop a ½ inch spark at the secondary terminals. It should never be run with a spark gap of ½ inch, as it might injure the secondary winding. For wireless it should only have a 3/16 inch gap with condensers bridged across it.

HOW TO BUILD CLOSED CORE TRANSFORMERS.

½ to 3 K. W. Capacity.

The construction of closed core transformers from ½ to 3 K. W. capacity will now be taken up in detail. The core will be the first thing to consider, and for a ½ K. W. size will be 7" wide, 14" long, and 1.4" thick. The width of the core is also 1.4" as shown in sketch below.

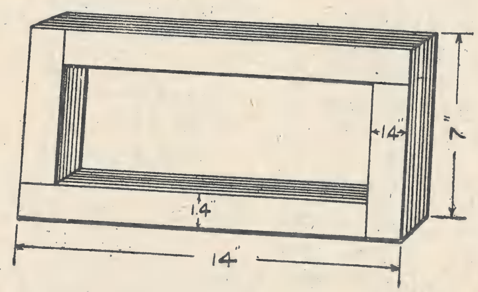


Figure 1

It will be seen that the iron breaks joint four times in each layer, and thus there will be two sizes of iron strips to be cut; one half the total number 1.4" x12.6" and the other half of them 1.4"x5.6". This iron should be very soft annealed stock, not over 1/32" thick, as otherwise there will be too great an eddy current loss, due to the stray currents set up in the iron mass. The method of assembling the iron core layers is shown in Fig. 2. As will be seen, the end of one strip overlaps the break in the strips below it, and forms practically a solid mass of iron

when finished. One end of the core is put in place, after the primary and secondary coils are wound and put in place. The core should have its three assembled legs, well taped with friction tape to bind the laminations firmly together.

Over the two longer legs A and B, Fig. 2, wind 9-10 layers of empire cloth, making an insulating wall about ¼" thick. This cloth should be the same length as the interior opening in the core.

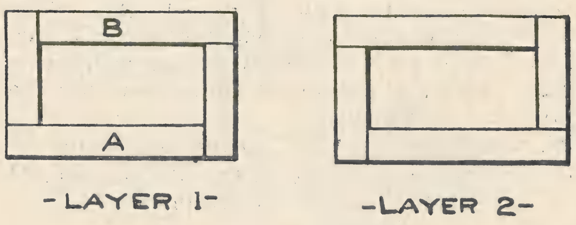


Figure 2

We now come to the primary winding, and in the sizes of transformers to be considered here, there will be brought out from it, leads from each layer so that the inductance and also the secondary voltage may be varied as desired.

The primary winding for the ½ K. W. transformer, will consist of 480 turns of No. 13 B. & S. D. C. C. magnet wire, wound in 4 layers, bringing out taps from the ends of the 2nd, 3rd and 4th layers. This will require about 6 pounds of wire. The wire may be wound on a form and then slipped over one of the transformer legs, taping the coil with oiled linen bias tape or 1" strips of diagonally cut empire cloth. It is well to shellac each layer of the primary coil while winding it, and place soft rubber sleeving over each lead brought out, the leads being left about

10″ long. There should always be left a clearance of ½″ between the ends of the primary coil and the transformer iron.

The disposition of the several taps from the primary will be considered later on.

The secondary winding is to be made up of a number of pies or discs of wire, slipped onto the core and so inter-connected that the current traversing them will always pass around the core in the same direction. The easiest way to get this straight is to wind all the pies in the same direction, and then reverse every other one in assembling, connecting first two inside leads together, then two outside leads, etc., until the whole secondary has been properly connected. A glance at Fig. 3, will show how the connecting is accomplished.

The path taken by the current in passing through the coil sections can be easily traced, also that pie No. 2, is reversed in relation to pie No. 1.

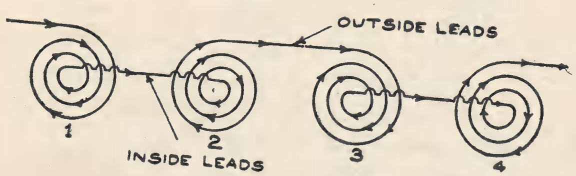


Figure 3

The secondary of the ½ K. W. transformer consists of 8 pound No. 34 D. C. C. wire, wound in 25 pies of 2092 turns each. The weight of each pie is 5.12 ounce and the thickness ¼″. The size of the inside opening in the pies is 1.9″ square. To impregnate the wire with wax, place the spools of wire in a pail containing melted paraffine wax, and let them

remain until all bubbles cease to arise to the surface of the hot wax. The wire may be wound on to a form, such as described in the chapter on "Induction Coil Construction," while it is hot from the impregnating bath, but another very good method is illustrated in Fig. 4. Here a small flame is placed below the impregnated spool of wire, which is placed 2 or 3 feet above the flame on a metal rod, which keeps the wax soft while being wound onto the form.

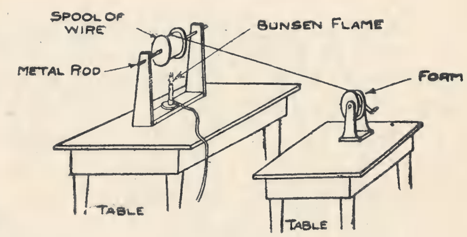


Figure 4

After the 25 pies have been wound, they should be taped with ¾″ strips of bias cut empire cloth, or regular oiled linen tape. Care must be taken in taping these pies, so that the leads do not lay against several layers of wire, which will cause a breakdown by the current trying to take a shorter path through the insulation and into the lead wire.

The secondary coil is now to be assembled, and the pies are placed on the core in units of two pies each. Two discs of empire cloth, a little larger than the pie, are placed between them, and their inside leads connected together, by soldering, and then taping the joint.

Place 4 discs of empire cloth between each unit of 2 pies, and proceed to assemble the whole secondary

in this manner, making sure that no coils are reversed in position, which would cause the current to pass around the core in the wrong direction. When all the pies are in place, there will be left on the outside the outer leads only to connect, which can easily be done.

There should be left a space of 1″ between the end of the secondary coil and the iron core, otherwise the transformer will break down, by the secondary discharge jumping to the iron.

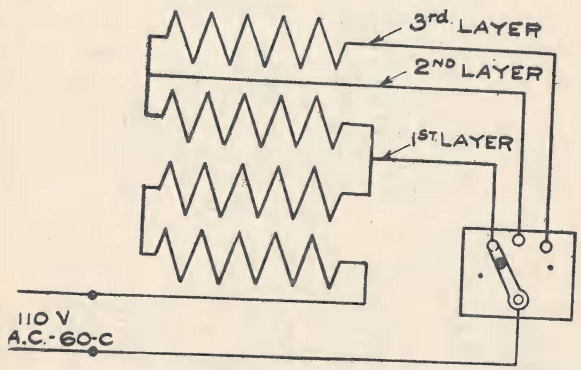


Figure 5

The transformer may be operated the way it is, but will soon break down. To avoid this, it should be placed in a wood or metal case, filling the case with a regular impregnating wax, transil oil, or a wax composed of 1 pound of beeswax, 1½ pound paraffine and 4 pounds rosin.

The primary leads are to be connected up to a suitable switch as in Fig. 5. It should have a hard-rubber or fibre base.

This transformer is to run on a 110 volt, 60 cycle alternating current circuit. At full load with all four

primary layers cut in, it will consume 5 amperes, at an efficiency of 94 per cent, which gives a secondary current of .046 amperes at 11,908 volts pressure. On 3 layers of primary the secondary voltage is 17,460 volts, and on 2 layers the secondary voltage will be 23,012 volts.

The data for closed core transformers of 1 K. W., 2 K. W., and 3 K. W., are given in the appendix at the end of the book, also dimensions, etc., of open core transformers.

HOW TO FIND THE CAPACITY OF A CONDENSER.

The capacity of a condenser may be calculated by the formula:

$$C \text{ (in microfarads)} = \frac{2248 \text{ K a}}{\text{d } 10^{10}};$$

in which (K=) inductivity value; (a=) area of dielectric surface between charging surfaces; (d=) thickness of dielectric in inches.

To find the joint capacity of several condensers connected on multiple, add their individual capacities thus ($C_1+C_2+C_3$, Etc=C joint.)

The capacity of several condensers connected in series, is found by the formula.

$$C \text{ joint} = \frac{1}{\frac{1}{C}+\frac{1}{C_2}+\frac{1}{C_3}+\text{Etc.}};$$

FINIS.

APPENDIX

Practical Tables Used In Constructing

SPARK COILS AND TRANSFORMERS.

DATA ON CONDENSER CONSTRUCTION.

IRON CORE DIMENSIONS.

SPARKING DISTANCES.

WIRE VALUES, ETC.

TABLE OF SPARK COILS

Dimensions, Suitable for X-rays, Demonstrations, Electrotherapeutics and Experimental Work.

LENGTH OF SPARK	1"	2"	3"	6"	8"	10"	12"	14"	16"	18"	20"
LENGTH CORE	7.5"	9.5"	11.5"	14.0"	17.0"	17.0"	18.0"	18.0"	19.0"	20.0"	20.0"
DIAMETER CORE	1.0"	1.0"	1.25"	1.25"	1.5"	1.5"	1.6"	1.6"	1.75"	2.0"	2.0"
No. PRIM. WIRE	18	16	14	12	12	12	12	12	10	10	10
INSIDE DIAMETER OF TUBE	1.32"	1.5"	1.75"	1.75"	2.0"	2.0"	2.12"	2.12"	2.25"	2.5"	2.5"
WALL OF TUBE	$\frac{1}{16}$"	$\frac{1}{8}$"	$\frac{3}{16}$"	$\frac{1}{4}$"	$\frac{1}{4}$"	$\frac{5}{16}$"	$\frac{3}{8}$"	$\frac{3}{8}$"	$\frac{3}{8}$"	$\frac{1}{2}$"	$\frac{1}{2}$"
DIAM. OF PIES	3.5"	4.0"	4.0"	4.5"	6.25"	6.25"	6.5"	7.0"	7.5"	8.5"	9.5"
No. OF PIES	8	20	30	40	64	80	90	100	120	130	160
LENGTH OF SECONDARY	5.5"	8.0"	9.5"	10.0"	11.0"	11.25"	14.0"	14.5"	15.5"	16.0"	16.0"
WEIGHT SEC. WIRE, LBS.	1.0	2.0	3.0	7.5	9.5	11.0	13.0	15.0	17.0	19.0	21.0
No. OF SEC. WIRE	36	36	36	34	34	34	34	34	34	34	34
AREA TINFOIL Sq. IN.	1000	2000	2400	4500	8300	8500	10000	12500	14000	20000	24000
PRIM VOLTS	8	12	14	18	22	22	24	24	28	28	32

Secondaries are wound with S. S. C. wire throughout.

Secondaries with S. C. C. wire on them will require about 30 per cent. more wire.

TABLE OF DIMENSIONS OF SPARK COILS

Suitable for Use in Wireless Telegraphy — These Coils Give a Very Heavy Fat Spark.

LENGTH OF SPARK	$\frac{1}{8}$	$\frac{1}{4}$"	$\frac{3}{8}$"	$\frac{1}{2}$"	$\frac{3}{4}$"	1"	2"	3"	6"	12"
LENGTH OF CORE	3"	$3\frac{3}{4}$"	$4\frac{3}{4}$"	6"	7"	$8\frac{1}{2}$"	11"	$12\frac{1}{2}$"	16"	21"
DIAMETER CORE	$\frac{1}{4}$"	$\frac{3}{8}$"	$\frac{1}{2}$"	$\frac{1}{2}$"	$\frac{3}{4}$"	1"	$1\frac{1}{8}$"	$1\frac{3}{8}$"	$1\frac{5}{8}$"	$1\frac{7}{8}$"
No PRIM. WIRE	23	23	22	19	16	16	14	14	12	10
LAYERS PRIM.	2	2	2	2	2	2	2	2	2	3
No SEC. WIRE	34	34	34	34	34	34	33	32	32	30
WGT. SEC. WIRE	$\frac{1}{4}$ LB.	$\frac{1}{2}$ LB.	$\frac{3}{4}$ LB.	1 LB.	$1\frac{1}{2}$ LBS.	2 LBS.	4 LBS.	8 LBS.	16 LBS.	30 LBS.
No. SEC. PIES	1	1	2	2	4	4	8	16	32	80
No. TINFOIL SHEETS	30	45	55	65	80	120	120	180	220	300
SIZE OF SHEET	2"x1"	2"x$1\frac{1}{2}$"	4"x2"	4"x2"	4"x4"	7"x5"	9"x7"	9"x7"	9"x9"	12"x8"
WALL OF INSUL. TUBE	$\frac{1}{32}$"	$\frac{3}{64}$"	$\frac{1}{16}$"	$\frac{1}{16}$"	$\frac{1}{8}$"	$\frac{1}{8}$"	$\frac{3}{16}$"	$\frac{1}{4}$"	$\frac{5}{16}$"	$\frac{3}{8}$"
PRIM. VOLTS	2	2	4	4	6	12	12	12	16	20

TABLE OF SPARK COIL DIMENSIONS

With Secondaries of Enameled Wire—Suitable for X-rays, Experimental Work, Etc.

Length of Spark	1/4"	1/2"	1"	2"	3"	4"	5"	6"	8"	10" *
Length of Core	5 1/2"	5 1/2"	5 3/4"	7"	8"	8 3/4"	9 1/2"	10"	14"	24"
Diameter of Core	1/2"	1/2"	1/2"	5/8"	3/4"	1"	1"	1 1/4"	1 1/2"	3"
Kind of Insulation over Core	Cardboard Tube		Cardboard Tube & Empire Cloth		Empire Cloth					
Thickness of Insulation over Core	1/16"		Tube 1/16" 2-Layers Cloth		2-Layers	3-Layers				4-Layers
No. B. & S.-D. C. C. Primary Wire	20	20	18	16	16	16	16	14	14	12
No. Turns Primary Wire	225	225	170	184	208	232	256	214	320	400
Kind of Insulating Tube	Empire Cloth							Micanite		
Thickness of Insulating Tube	4-Layers		6-Layers		8-Layers			1/8"	3/16"	1/4"
No. B. & S. Enamel Secondary Wire	No. 38			No. 36						28
Weight of Secondary Wire	3 oz.	4 oz.	3/4 lb	1-lb	1 1/2 lbs.	2-lbs	3-lbs.	5-lbs	8-lbs.	20 lbs
No. Pies in Secondary	1	1	2	4	4	8	12	16	24	40
Diameter of Secondary Pies.	1 3/8"	1 5/8"	1 3/4"	2 1/4"	3"	4"	4 1/2"	5"	8"	11"
Distance Between Coil Heads	4 1/4"	4 1/4"	4 1/2"	5 3/4"	6"	6"	6"	6 1/2"	7"	12"
Total Area in Sq. In Condenser Tinfoil	250	300	800	1400	2,000	2,500	3,000	6,000	8,500	10,500

*This coil is suitable for wireless telegraphy.

CLOSED CORE TRANSFORMER DATA

For Use on 110 Volts, A. C. 60 Cycles.

Capacity in Kilowatts	Length Iron in Inches	Width of Iron in Inches	Thickness & Width Core	No Primary Wire D.C.C.	Weight Prim. Wire in Lbs.	Layers in Primary	Prim. Current in Amperes at Full Load	Weight of Iron in Lbs.	Length Prim. Coil in Inches	Weight of Sec. Wire Lbs.	No Pies 1/4" Thick	Turns per Pie	Size of Sq. Opening in Pie	Length of Secondary Winding.	Amperes in Sec. Lowest Voltage	Sec Voltage on 4 Layers of Primary	Sec Voltage on 3 Layers of Primary	Sec Voltage on 2 Layers of Primary	Per Cent of Efficiency	No Sec Wire D.C.C.	Average Sending Range in Miles in Daylight over Land *
1/2	14	7	1.4	13	6	4	5	20	10.2	8	25	2092	1.9"	9.2"	.046	11908	17460	23012	94	34	75
1	15	8 1/4	2	10	11.3	4	9.6	41	10	11	24	1611	2.5"	9"	.086	12363	18261	24880	94	32	150
2	17 1/2	8 3/4	2 1/4	8	13.5	3	18.2	56	12	21	30	920	2.75"	11"	.153		12440	16580	95.7	28	300
3	18	9 1/2	2 1/2	6	19	3	27.3	75	12	27	30	708	3"	11"	.252		11920	15893	96.5	26	450

OPEN CORE TRANSFORMERS.

For Use on 110 Volts, A. C. 60 Cycles.

Capacity in Kilowatts	Length of Core in Inches	Diameter of Core in Inches	No B & S D C C Prim Wire	Layers in Primary	No B & S S S C Sec Wire	No of Pies 1/4" Thick	Weight of Secondary Wire	Thickness Wall of Hard Rubber Tube over Prim. and Same Length †		Average Sending Distance in Miles in Daylight over Land
1/2	11	1 1/4	14	2	34	26	8	1/4"		75
1	14	1 1/2	12	2	32	30	12	3/8"		150
1 1/2	16	2	12	2	30	52	18	1/2"		250
2	18	2 1/2	10	2	28	60	22	5/8"		300
3	24	3	8	3	26	70	30	3/4"		450

*Sending distance over water or at night is twice this value.
†Pies to be insulated from one another by two discs of empire cloth.

HIGH POTENTIAL GLASS PLATE CONDENSERS FOR WIRELESS TRANSFORMERS.

Kilowatts Capacity	Total No. Glass Plates for Series Parallel Condenser of 2 Units	Size of Glass Plates — Thickness .05 Inches	Size of Metal Foil Leaves	Microfarads* Capacity at 60 Cycles
$\frac{1}{4}$	18	12" x 14"	8" x 10"	.0048
$\frac{1}{2}$	34	12" x 14"	8" x 10"	.0095
1	40	16" x 19"	10" x 13"	.019
2	80	16" x 19"	10" x 13"	.037
3	120	16" x 19"	10" x 13"	.056
4	160	16" x 19'	10" x 13"	.074
5	200	16" x 19"	10" x 13"	.093

Note: *Microfarads capacity required at 120 cycles will be one-half this value.

HIGH POTENTIAL GLASS PLATE CONDENSERS FOR INDUCTION COILS.

Length of Spark in Inches	Total No. Glass Plate for Multiple Condenser of 1 Unit	Size of Glass Plates — Thickness .05 Inches	Size of Metal Foil Leaves	Microfarads Capacity
$\frac{1}{2}$	3	8" x 10"	6" x 8"	.0024
1	6	8" x 10"	6" x 8"	.004
2	12	8" x 10"	6" x 8"	.008
3	18	8" x 10"	6" x 8"	.012
6	14	16" x 19"	10" x 13"	.024
8	18	16" x 19"	10" x 13"	.032
10	22	16" x 19"	10" x 13"	.040
12	28	16" x 19"	10" x 13"	.048

TABLE OF SPARKING DISTANCES
In Air for Various Voltages Between Needle Points.

Volts	Distance		Volts	Distance	
	Inches	Centimeter		Inches	Centimeter
5000	225	.57	60000	4.65	11.8
10000	470	1 19	70000	5 85	14.9
15000	725	1 84	80000	7 10	18.0
20000	1.000	2 54	90000	8 35	21.2
25000	1 300	3 30	100000	9 60	24.4
30000	1 625	4 10	110000	10 75	27.3
35000	2.000	5 10	120000	11 85	30 1
40000	2 450	6 20	130000	12 95	32 9
45000	2 95	7 50	14000	13 95	35 4
50000	3 55	9 00	15000	15.00	38.1

INDUCTIVITY VALUES FOR DIFFERENT DIELECTRICS.

Dielectric	Inductivity Value, "K"
Air at ordinary pressure, standard	1.0000
Manilla paper	1.50
Paraffine, clear	1.68 to 2.32
Beeswax	1 86
Paraffine wax	1.9936 to 2 32
Paraffined paper	3.65
Resin	1 77 to 2 55
Petroleum	2.03 to 2.42
Hard rubber (Ebonite)	2.05 to 3.15
Turpentine	2.15 to 2.43
India rubber, pure	2 22 to 2.497
Sulphur	2 24 to 3 84
Gutta percha	2 46 to 4.20
Shellac	2.74 to 3.60
Olive & neats-foot oils	3.00 to 3.16
Sperm oil	3.02 to 3.09
Glass (common)	3.013 to 3.258
Mica sheet, pure	4 00 to 8.00
Porcelain	4.38
Quartz	4.50
Flint glass, very light	6.57
" " , light	6.85
" " , very dense	7.40
" " , double extra dense	10 10

TABLE OF INSULATED MAGNET WIRE.

SIZE. B & S GAUGE	TURNS PER LINEAR INCH				
	ENAMELED	SINGLE COTTON	DOUBLE COTTON	SINGLE SILK	DOUBLE SILK
20	29	25	23	27	26
21	32	28	26	31	29
22	36	31	28	34	32
23	41	34	31	38	36
24	45	37	33	42	39
25	51	41	36	47	43
26	56	45	39	52	46
27	64	49	42	57	52
28	71	54	45	63	56
29	79	58	48	70	62
30	88	64	57	77	67
31	100	69	56	85	72
32	112	75	60	93	78
33	134	81	64	102	84
34	140	87	68	112	91
35	156	94	73	120	97
36	173	101	78	130	104
37	201	108	84	141	110
38	225	115	89	151	117
39	256	122	95	163	123
40	288	130	102	178	129

DOUBLE COTTON.

SIZE B. & S. GAUGE	NO. TURNS PER LINEAR INCH	SIZE B. & S. GAUGE	NO. TURNS PER LINEAR INCH
4-0	1.70	7	6.08
3-0	2.00	8	6.80
2-0	2.32	9	7.64
1-0	2.65	10	8.51
1	2.99	11	9.56
2	3.36	12	10.60
3	3.80	13	11.88
4	4.28	14	13.10
5	4.83	15	14.68
6	5.44	16	16.35

FEET PER POUND OF INSULATED MAGNET WIRE.

NO. OF B. & S. GAUGE	SINGLE COTTON 4-MILS	DOUBLE COTTON 8-MILS	SINGLE SILK 1¾-MILS	DOUBLE SILK 4 MILS	ENAMEL
20	311	298	319	312	320
21	389	370	403	389	404
22	488	461	503	493	509
23	612	584	636	631	642
24	762	745	800	779	810
25	957	903	1005	966	1019
26	1192	1118	1265	1202	1286
27	1488	1422	1590	1543	1620
28	1852	1759	1972	1917	2042
29	2375	2207	2570	2485	2570
30	2860	2534	3145	2909	3240
31	3800	2768	3943	3683	4082
32	4375	3737	4950	4654	5132
33	5390	4697	6180	5689	6445
34	6500	6168	7740	7111	8093
35	8050	6737	9600	8534	10197
36	9820	7877	12000	10039	12813
37	11860	9309	15000	10666	16110
38	14300	10636	18660	14222	20274
39	17130	11907	23150	16516	25519
40	21590	14222	28700	21333	32107

WEIGHT OF SOFT IRON WIRE CORES OF VARIOUS SIZES.

LENGTH IN INCHES / DIAMETER	4"	5"	6"	7"	8"	9"	10"	11"	12"	13"	14"	15"	16"	17"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"
1/2"	17	21	.25	.29	.33	.37	.41	.46	.50	.54	.58	.62	.66	.70	75	.83								
5/8"	26	33	.39	.46	.52	.59	.65	.72	.78	.85	.91	.98	1.04	1.11	1.17	1.30	1.43							
3/4"	.38	47	.56	.66	75	.84	.94	1.03	1.13	1.22	1.31	1.41	1.50	1.59	1.69	1.88	2.06	2.25						
7/8"	.51	64	.77	.89	1.02	1.15	1.28	1.40	1.53	1.66	1.79	1.92	2.04	2.17	2.30	2.55	2.81	3.07	3.32	3.58				
1"	67	.83	1.00	1.17	1.33	1.50	1.67	1.83	2.00	2.17	2.33	2.50	2.67	2.83	3.00	3.33	3.67	4.00	4.33	4.67	5.00	5.33		
1 1/8"	.84	1.05	1.27	1.48	1.69	1.90	2.11	2.32	2.53	2.74	2.95	3.17	3.38	3.59	3.80	4.22	4.64	5.06	5.49	5.91	6.33	6.75	7.17	7.60
1 1/4"	1.04	1.30	1.56	1.82	2.08	2.34	2.60	2.87	3.13	3.39	3.65	3.91	4.17	4.43	4.69	5.21	5.73	6.25	6.77	7.29	7.81	8.34	8.86	9.38
1 3/8"	1.26	1.58	1.89	2.21	2.52	2.84	3.15	3.47	3.78	4.10	4.41	4.73	5.04	5.36	5.67	6.30	6.93	7.56	8.19	8.82	9.46	10.1	10.7	11.3
1 1/2"	1.50	1.87	2.25	2.62	3.00	3.37	3.75	4.12	4.50	4.87	5.25	5.63	6.00	6.37	6.75	7.50	8.25	9.00	9.75	10.5	11.3	12.0	12.7	13.5
1 5/8"		2.20	2.64	3.08	3.52	3.96	4.40	4.84	5.28	5.72	6.16	6.60	7.04	7.48	7.92	8.80	9.68	10.6	11.4	12.3	13.2	14.1	15.0	15.8
1 3/4"		2.55	3.06	3.57	4.08	4.59	5.11	5.62	6.13	6.64	7.15	7.66	8.17	8.68	9.19	10.2	11.2	12.3	13.3	14.3	15.3	16.3	17.4	18.4
1 7/8"			3.52	4.10	4.69	5.27	5.86	6.45	7.03	7.62	8.20	8.79	9.38	9.86	10.5	11.7	12.9	14.1	15.2	16.4	17.6	18.8	19.9	21.1
2"			4.00	4.67	5.33	6.00	6.67	7.33	8.00	8.67	9.34	10.0	10.7	11.3	12.0	13.3	14.7	16.0	17.3	18.7	20.0	21.3	22.7	24.0
2 1/8"				5.27	6.02	6.77	7.53	8.28	9.03	9.79	10.5	11.3	12.0	12.8	13.5	15.1	16.6	18.1	19.6	21.1	22.6	24.1	25.6	27.1
2 1/4"				5.91	6.75	7.60	8.44	9.28	10.1	11.0	11.8	12.7	13.5	14.3	15.2	16.9	18.6	20.3	21.9	23.6	25.3	27.0	28.7	30.4
2 3/8"					7.52	8.46	9.40	10.3	11.3	12.2	13.2	14.1	15.0	16.0	16.9	18.8	20.7	22.6	24.4	26.3	28.2	30.1	32.0	33.9
2 1/2"					8.33	9.37	10.4	11.5	12.5	13.5	14.6	15.7	16.7	17.7	18.8	20.8	22.9	25.0	27.1	29.2	31.2	33.3	35.4	37.5
2 5/8"						10.3	11.4	12.6	13.8	14.9	16.1	17.2	18.4	19.5	20.7	23.0	25.3	27.6	29.9	32.2	34.5	36.8	39.1	41.4
2 3/4"						11.3	12.6	13.8	15.1	16.4	17.6	18.9	20.2	21.4	22.7	25.2	27.7	30.3	32.8	35.3	37.8	40.3	42.9	45.4
2 7/8"							13.8	15.2	16.5	17.9	19.3	20.7	22.0	23.4	24.8	27.6	30.3	33.1	35.8	38.6	41.3	44.1	46.8	49.6
3"							15.0	16.5	18.0	19.5	21.0	22.5	24.0	25.5	27.0	30.0	33.0	36.0	39.0	42.0	45.0	48.0	51.0	54.0

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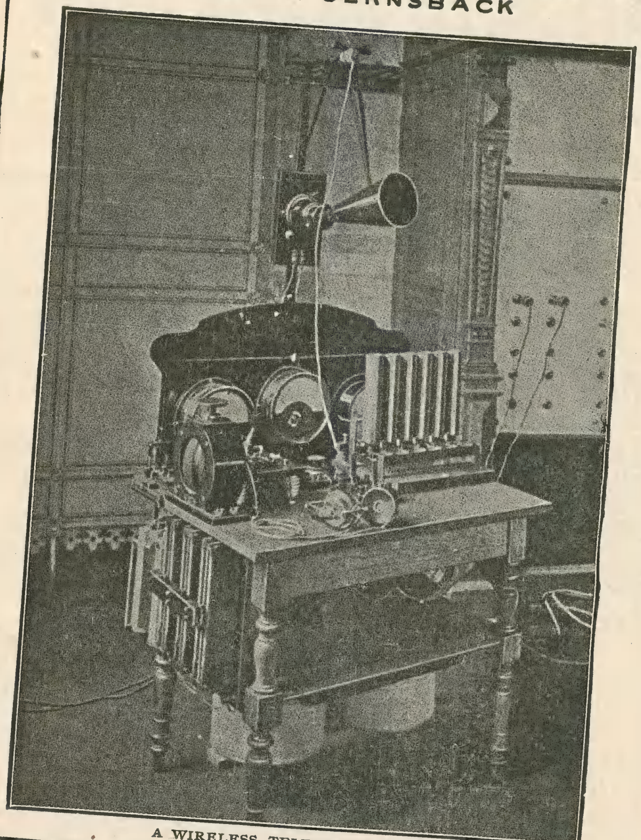

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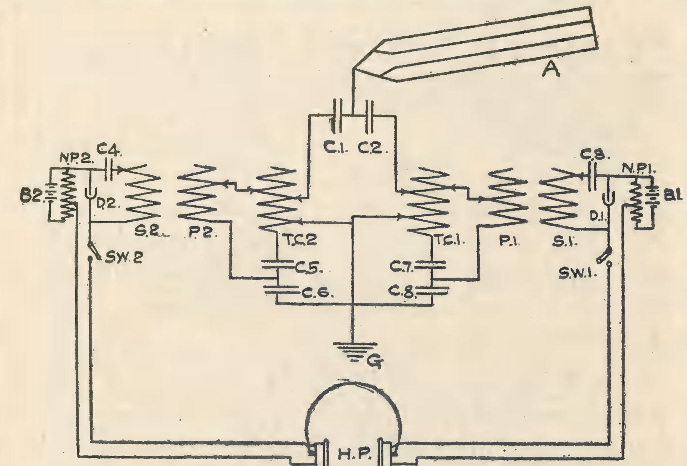

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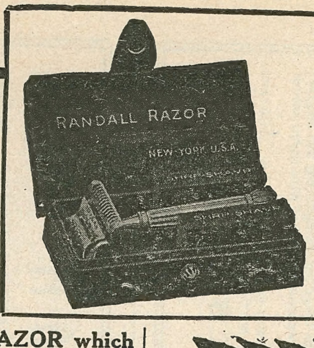

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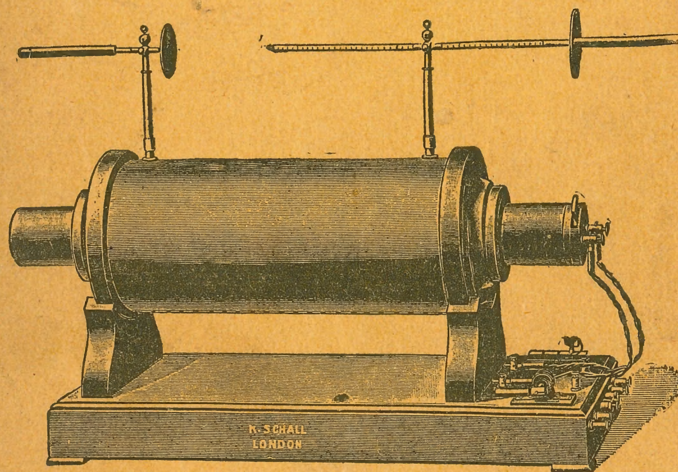

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